TACTILE GRAPHICS

Polly K. Edman

American Foundation for the Blind

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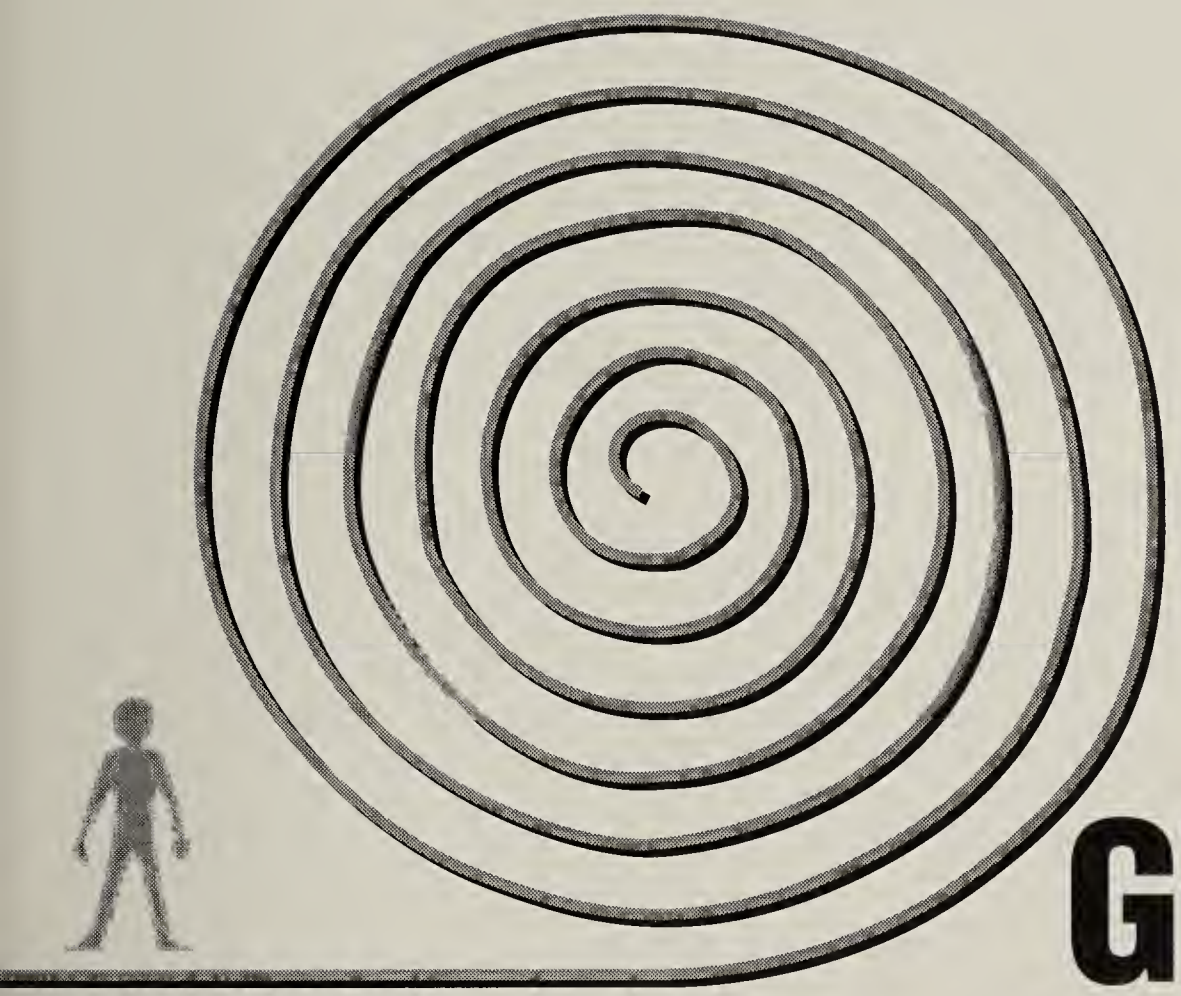

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Polly K. Edman

American Foundation for the Blind
New York

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1992
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The mission of the American Foundation for the Blind (AFB) is to enable persons who are blind or visually impaired to achieve equality of access and opportunity that will ensure freedom of choice in their lives. AFB accomplishes this mission by taking a national leadership role in the development and implementation of public policy and legislation, informational and educational programs, diversified products, and quality services.

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During a session of an international conference, discussion of the subject of standardized symbols for tactile displays became heated. After two hours, a quiet man stood up in the back of the room. He introduced himself as a representative of one of the developing countries. "This is all very fine," he said, "but tell me—how does one begin?" To him and to everyone else who has been confronted with this question, I dedicate this book.

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Foreword

This book is a landmark. Those of you opening it for the first time are about to gain access to what is to our knowledge the most comprehensive collection of information available on how to render printed material into a tactile—that is, readable—form for blind and visually impaired people. Those of you who are using the book now already know about the magnificent array of material that is here at hand, in one source, and written in a simple, easy-to-understand way that any reader can follow. This informative and exciting book offers more in a more easily usable way than has ever previously been offered on the subject of tactile graphics.

What's so important about tactile graphics? The applications of the subject, always important, have taken on new significance for blind and visually impaired persons recently. Translating visual information into a tactile form that blind and visually impaired persons can understand is at the heart of making information accessible to these readers. Ready access to information means improved opportunities for literacy, education, employment, and independent travel, to name a few areas, for people who are blind or visually impaired. Access to information is such a fundamental issue for blind and visually impaired persons that it is a top priority for all of us at the American Foundation for the Blind (AFB). With the recent passage of the Americans with Disabilities Act, it has become an issue for the United States as a whole and for other countries as well.

Tactile Graphics is the lifework of Polly K. Edman, who was

head of production of graphics at RPH-SYN, the National Center for Educational Aids for the Blind in Solna, Sweden, for 12 years. Mrs. Edman is a remarkable woman who has worked for more than 30 years as a graphic artist and designer, author and illustrator, and producer of tactile materials. In addition to her far-ranging knowledge and expertise, she has brought to this book an advocate's passion about the need to make materials for blind and visually impaired persons that meet their requirements, not those of sighted readers. Her conviction and insistence have not only made a contribution to the blindness field in the form of the material you see here, but have also performed an important service that will help improve the lives of blind and visually impaired persons.

Welcome to the fascinating world of tactile graphics. This book will tell you everything you need to know about how to make tactile material for blind and visually impaired readers. A wealth of ideas and information is now yours. We at AFB are delighted to have helped to provide it.

Carl R. Augusto
President and Executive Director
American Foundation for the Blind

Preface

My main desire has always been to show people interested in visually impaired persons the how and why of the many different ways in which relief materials can be produced. This is an occupation that started more than 30 years ago and one that I have enthusiastically followed ever since.

In 1959 I was abruptly introduced to the world of the blind through an accident that left me sightless for several months. I subsequently changed my occupation from commercial graphics and the production of two-dimensional illustrations to the production of three-dimensional figures—that is, to the construction of tactile graphics. The transition was not an easy one. When I first began working on tactile displays for children, parents and teachers asked me to stop, saying I would only frustrate the children! But the children themselves asked for more pictures, and I was convinced that I was on the right track. The reaction of the children could not be ignored! I thought that their world of mental pictures must be quite similar to our world of sighted impressions. In the 1970s the raised-line drawing board made its appearance, and blind children began to draw. Their drawings were surprisingly similar to those of their sighted friends. My theories were confirmed.

Over the next 20 years I continued to make pictures and write stories for children. During this time relief pictures became widely accepted. In 1979 I was employed by RPH-SYN, the National Center for Educational Aids for the Blind, in Solna, Sweden (whose name, as this book went to press, has just been changed to SIH Laromedel I Solna). In Sweden, visually

impaired children attend integrated schools with children who do not have visual impairments. Consequently, the educational materials for both groups of students are quite similar, and the demand for these materials is inexhaustible. During my years at RPH-SYN, educators, parents, community officials, and mapmakers sent in clippings, textbooks, and, at times, their own illustrations to be transcribed by me into relief displays. The amount of material that I accumulated was immense, as was the number of hours that I spent with these people and with visually impaired students and adults to try and work out solutions that would best suit everyone's needs. The material that you see here in *Tactile Graphics* is the result of my many hours of creating tactile displays and of talking with people about such displays.

Over the years, pressure grew both nationally and internationally for tangible information that people could follow when confronted with problems relating to the production of relief material. A book was the logical solution, and this vast amount of information is now in your hands. The printed layouts used in this book, originally from Swedish books and materials, have, to a certain extent, been translated. In cases in which the original masters have been photographed, it was impossible to supply a braille translation from Swedish. Because of this, many of the illustrations appear with their original Swedish texts.

Most of the material presented in this book is the work I did in Sweden on the basis of these printed layouts and others. Every effort has been made to attribute materials to their original sources. There are tremendous complications involved in tracking down odd bits of information, obsolete as well as current source material, and illustrators living and dead who have supplied the graphics in textbooks throughout many years. Unfortunately, some of this information has been impossible to locate as a result of the closing or merging of publishing houses in Sweden, but what has been located has been credited as accurately as possible.

Over the years, I have worked with a great number of people in many different countries. At this point, I would like to extend a heartfelt word of thanks to Kerstin Fellenius, teacher of and consultant for visually impaired students, and to Harriette Kosterman, translator and editor, for their invaluable help and encouragement.

A word about the techniques and materials discussed in this book is also in order. None of the techniques described in this book is unsafe provided that you use care and discretion when handling the materials, tools, and machines. I would like to stress the necessity of using a well-ventilated room when mass-producing vacuum-formed plastic copies or microcapsule paper copies of your displays. Good ventilation is also important when working with solder, glues, and any other material that might give off fumes, especially when being heated. In addition, vigilance when working with the sharp edges of cutting implements and the heated surfaces of certain machines in operation is always in order.

A great deal of research is still needed to develop more understandable and useful tangible graphic displays. There is also an ever-increasing demand for relief material. So until the time comes when definitive guidelines can be put into print, it is up to each of us, using the best of our abilities, to create displays that we think are effective for our particular purpose and group of readers. We can do so by keeping an open mind, continually testing our work, and improving our knowledge and techniques by sharing information and methods with others in the field. I hope this handbook is a stepping-stone in this direction.

This book is not a definitive authority on the production of tactile graphics; it is meant to stimulate your thoughts and help you along the way. Coupled with your own experiences, it should be able to assist you in helping a great many people. Good luck, it's an exciting challenge to teach in relief!

Tactile Graphics

CHAPTER 1

Principles and Purposes

"...careful planning must be made when converting a visual image to a tactile one. It simply cannot be assumed that a graphic will be made meaningful to the blind by merely raising it above the surface point for point."

—John Barth, *The Tactile Graphics Guidebook*

This book has come about through the gathering together of the ideas and comments of many people, sighted and blind, producers and readers—people of many ages in many different countries. Their suggestions are intertwined with my findings, made over the years as a producer of relief materials for visually impaired people.

The information presented here cannot solve all the problems associated with the production of relief maps and pictures, but it may help you produce such materials more easily. The ideas and techniques in this book are ones I find applicable right now. Readers are making themselves heard, cooperation between producers and readers is increasing, and the quality of available graphics has improved over the past several years. New ideas are always appearing as more and more relief materials are produced, and these will eventually stimulate new methods to take the place of present ones.

OPPOSITE PAGE: Always keep in mind that each picture is to be felt, not seen!

Perhaps this book will act as a catalyst, enabling you to work out a different system for making maps and pictures that is even more suited to the needs of the visually impaired children, students, or adults with whom you come in contact. I hope that some of the ideas found here will give you new thoughts in this direction. There is so little usable relief material today, and there is so much that can be done!

INTRODUCTION

The points made in this handbook can be used to create tangible graphics at home or in school, as well as in the

production room of any commercial firm making tactile displays. Methods of production can vary from the simplest picture drawn on a raised-line drawing sheet to complicated computer diagrams transposed into relief pictures and maps. The basic principles of picture making are the same in *all* types of production.

The main ingredient of good picture making is *you*. The important factors are how you think, both with your mind and with your fingers. Can you put yourself in the place of your reader? How can you present your information—whether it is a picture, map, or graph—so that the important facts or features are clearly understood and unnecessary details are omitted? Can you evaluate the ability of your audience to comprehend, mentally and haptically, the material you produce?

OPENING THOUGHTS

There is a great deal to consider when putting together the simplest graphic design. If it is not well thought out, no amount of effort in its production will make the design more understandable to your reader. Always keep in mind that each picture is to be felt, not seen! Try to put yourself in the blind person's shoes. If you were given a relief picture, how would you know what you were looking at if you had never seen the object portrayed, never felt it or read a description of it? What would you have as a base of reference?

I believe all seeing is a learning process, whether it is done with your eyes or with your fingers. Gathering information and sorting out impressions is a mental activity that allows you to "see" things the way you do. Each one of us sees things differently. Seeing is a process of interpretation based on background experience, knowledge, and environment. You must *learn* to see, to form your own opinions. The result of these impressions on the senses is strictly subjective, whether you are sighted or not. The facts are present. How much you are able to understand about them depends on how receptive you are and on the rate at which you come into contact with different types of information.

For people who are blind, one of the most difficult problems to solve is proportion. For them, it is both a language problem and a graphic problem. References or visual experiences often allude to distances or sizes beyond those that blind people

can experience physically, and these allusions become abstract ideas. Because it may be difficult for blind and visually impaired people to understand perspective, size relationships, and related abstractions, they are forced to accept the sighted world's version of these situations without being able to evaluate them. With this in mind, it is not wise to take for granted that your opinion—or your way to make a display—is the only right one for these readers.

You may be able to help a blind or visually impaired person more effectively by trying to understand more about his or her world. Take every opportunity to be with visually impaired people. Talk with them, play with them, and listen to them. Be aware of their comments and criticisms, especially about material to be read. It may be difficult to get them to express their feelings. They may feel that you are testing their ability to understand or their intelligence. For example, few children will readily admit that they do not understand something they think they should. Do not let their reticence discourage you. Their reactions are important. They may lead you to a better way of thinking, which could lead you to produce better material in the future.

Give visually impaired readers as much tangible graphic material as you can, as early in their lives as possible. Describe the material verbally or in braille print. Very young children need someone to "talk" them through a picture. Nonbraille readers may need an explanatory recording. Older students may prefer a written text. And for all visually impaired people, the combination of words and graphics improves comprehension.

Children may need someone to "talk" them through a picture. Techniques used in pictures for children are discussed in Chapter 2; pictures by children are discussed in Chapter 5.

Our society is geared to visual impressions. More and more descriptive and instructive materials are pictorial, with or without the addition of printed words. International signs for traffic and information are obvious examples of this trend, as are television and other video-transmitted information. Our language is filled with words derived from visual experiences, words describing form, color, and direction, for example, such as sunset, rainbow, greenhouse, downpour, skyscraper, upside-down, a square meal. How do blind children or adults react to these constant reminders of visual images? What do these words really mean to them? Can you help them understand through the use of pictures?

THIS IS A PICTURE!

What is a picture? The answer can easily be explained to a young blind child by using a drawing board. Children the world over enjoy drawing pictures. Just because a child cannot see does not mean that he or she cannot achieve artistic expression through pictures. Perhaps that child has never even had a pen or pencil in his or her hand. And which hand would the child use? If the child is very young, you can find this out by rolling balls back and forth across the floor and observing the hand the child seems to use most while playing with the balls. An older child may already prefer the left or the right hand, and if so, will tell you this from the start.

Next, give the child a drawing board—a rubber pad covered with a thin sheet of plastic. Draw a line across the surface with a ballpoint pen. A welt is formed as the pen is pressed against the plastic. Let the child scribble on the page, and to his or her surprise, the wiggly lines will rise to form a relief. As the child becomes used to the pen, he or she will create more wiggles. Put a new sheet of plastic on the board. This time, place the child's hand on the sheet and help him or her draw around it. Then ask, "What's that?" as you feel the drawing together. "My hand" will be the reply. You may now say, "Oh no, your hand is still on the end of your arm." Both of you feel the page again. And you repeat, "What's that?" Most often, the answer is the same: "My hand." "No, it's not your hand," you reply. "It is a *picture* of your hand." The look of surprise and then delight that will appear on the child's face

has happened the world over. This is a picture! You have just filled an often-heard word with new meaning.

Now give the child some wooden blocks or other solid forms—a sphere, a cube, a pyramid. Feel them. Talk about them. Put them down on the drawing sheet and draw around them. The result is a circle, a square, and a triangle—the basic geometric forms. The child is soon drawing simple shapes. The square becomes a house; the circle a face. Talk about the pictures and the shapes and objects at hand. This exercise helps build up knowledge, memory of form, and understanding of pictures. Pictures are only flat versions of three-dimensional objects.

A child's early experience with tangible graphics will lay a solid foundation for the perception of relief drawing and increase his or her ability to understand with ease and speed the maps, pictures, and graphics he or she will encounter throughout school. The child's ability to understand and assimilate the information presented in these reliefs will increase in proportion to the amount of material with which he or she is confronted—provided, of course, that this relief material is produced in a clear, concise, and informative way in a well thought-out display that is made primarily for fingers, not for eyes.

Pictures for blind and visually impaired people should be recordings of facts if the material is to be used for educational purposes. These facts are presented through tactile symbols from which visually impaired individuals should be able to draw their own conclusions, on their own terms. In pictures, as in life, people with visual impairments must piece together bits of information received from their fingertips as they progress over the display. How they experience the picture and whether it has any value as an informative addition to their memory banks depends on their ability and the knowledge they have accumulated to understand and translate the forms. Consequently, it is up to you to present these facts in a simple, uncluttered layout.

PRACTICAL POINTS

If you are to avoid producing relief material more appropriate for a sighted person than a blind person, you must have the skill

to omit things, differentiate between the unessential and the essential, and occasionally draw outlines in an exaggerated way (see Tschirner, 1984). The main criterion is that the blind person should be able to identify and understand the relief picture or map.

A picture is only one way to organize the mind. It is a point of reference and can never take the place of a three-dimensional object. However, it may be a very important complement to such an object, and often it is a necessary one. Pictures are suitable:

- when an actual object is unavailable—for example, the stars, a skyscraper, a coal mine, or an elephant,
- when the scale of an actual object—such as an insect or a cell—is too small for a detailed study,
- when the scale of an object is too large to be physically understood in its complete form—such as with the solar system, a tree, or a mountain,
- when it is difficult to explain a phenomenon in words—a rainbow, smoke from a chimney, the natural cycle of water, for instance,
- when the object cannot be touched—it may be too breakable, as are soap bubbles or snow flakes, or it may be too dangerous, as are poisonous things or things to which the reader may be allergic,
- when clarifying a route between points A and B—analyzing a room, for example, or using orientation maps,
- or when it is necessary to describe size relationship between objects—such as an elephant and a man, a house and a tree.

The following are some points to think about when planning a tactile graphic display.

The type of picture or map that is needed can be determined by considering:

- Why this picture or map is necessary—choose the most important elements to portray.
- Who will use this material—age group, both mental and physical; ability to read braille; ability to read large relief inkprint letters and numbers; familiarity with tactile graphics.

- How this picture or map will be used—with or without help from a sighted person, with other children who are sighted or blind (there is a psychological aspect here), with three-dimensional objects, with a tape recording, with a braille text.
- And where this material will be used—in school as textbooks or maps, at home for leisure reading or games, in the field as mobility and orientation maps. Each location has its special requirements—the material may have to be waterproof, foldable, large or pocket-size, usable on the wall or on a table, and so on.

How the picture or map will be produced depends on:

- The ultimate use of the display—to be used for one copy or many copies, to be kept or thrown away after use, to be used outdoors or indoors.
- The number of readers using the material. Often tactile graphic displays are made for one particular person or for a small group of people who will be using the material together. In such cases, it may not be necessary to make several copies of the same picture or map. Mass production must be considered when a larger group of readers—such as schools, associations, libraries, and communities—need relief materials. (Various methods and techniques for the production of one or more copies are found in Chapter 2.)

The vacuum-forming machine—described in Chapter 2—is one effective tool that can be used to make copies of a display.

The source of information on which the picture or map is based may be:

- Factual data—from textbooks, encyclopedias, atlases,
- Teachers, doctors, technicians, musicians, cartographers,
- Schools, museums, libraries, public archives,
- Blind and visually impaired people themselves and their associations.

Changes might have to be made in the original source material; if the picture or map is to be based on available, factual, inkprint illustrations or maps, a certain amount of editing may need to be done on the original information:

- The display might need to be enlarged or diminished before making a copy in relief.
- Perhaps the display should be redrawn to suit the blind or visually impaired person's particular needs. Perspective might need to be eliminated or simplified. One should consider if it should be broken down into several pictures for a step-by-step type of display.
- Extraneous lines, unnecessary background, confusing forms, and cluttered areas should be removed from the original illustration, diagram, or map, as well as from all inkprint text.

Note: It is essential to establish the right to use original source material, since most printed material is protected by copyright. This term designates the rights secured by international law to authors, artists, and other creators of original material to protect their work against unauthorized copying. A copyright notice and date appear in most textbooks and other publications. Check with the publisher, author, or artist for permission to convert the work into material for visually impaired persons. This procedure should be done before you begin work on a tactile graphics display.(In my many years as a producer of relief materials, I have never been denied the use of copyrighted material.) Another official approval called approval of distribution applies to maps, and this is discussed in Chapter 6.

THE NEED FOR RELIEF MATERIAL

Tangible graphics are a recognized part of today's education of visually impaired readers, and the need for producers of relief material is great. The need for relief material itself is endless:

- Preschool children need pictures of people, pets, and objects in their surroundings; pictures to illustrate their storybooks; figurative or nonfigurative displays; comic strips using simple stick figures drawn on a drawing board; game boards; and playing cards made in relief.
- Students need a wider range of materials, from textbook displays to single-sheet material, pictures, maps, charts, and mathematical diagrams.
- Blind and visually impaired persons at work need instruction manuals, reference materials, information leaflets, machine descriptions in braille and in tangible graphic displays, material-handling charts, flow sheets, diagrams for computers, orientation maps (indoors for factory and offices and outdoors for surrounding areas and transportation routes), and maps of the community, the county, and the country.
- Casual readers need illustrations for novels, technical books, and journals; sport and hobby illustrations of games, playing fields, and diagrams; braille music and instrument diagrams; weather forecast maps, timetables, and calendars; mobility and orientation maps; and medical, child care, and anatomical illustrations.
- Older blind and visually impaired people need maps of areas showing principal towns or cities, railways, rivers, and roads, to assist them when traveling or listening to news items on the radio or television.

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CHAPTER 2

Production Methods and Materials

Methods of producing tactile graphics for blind and visually impaired people range from drawing relief figures on a simple and effective raised-line drawing board to using computer graphics. Sometimes one drawing is made; sometimes several copies of a drawing are needed. When copies are made, the original drawing is used as a master for duplication. Therefore, knowing techniques both for making original drawings and for duplicating masters is important. All methods are dependent on a good understanding of the framework and principles—the dos and don'ts—governing the making of relief material, whatever the number of items to be produced.

Many processes can be done at home or in schools, often under primitive circumstances. They cost very little, and the major investments are your time and imagination. Other processes are dependent on special tools and reproductive equipment that are obtainable from commercial manufacturers or national societies for visually impaired persons.

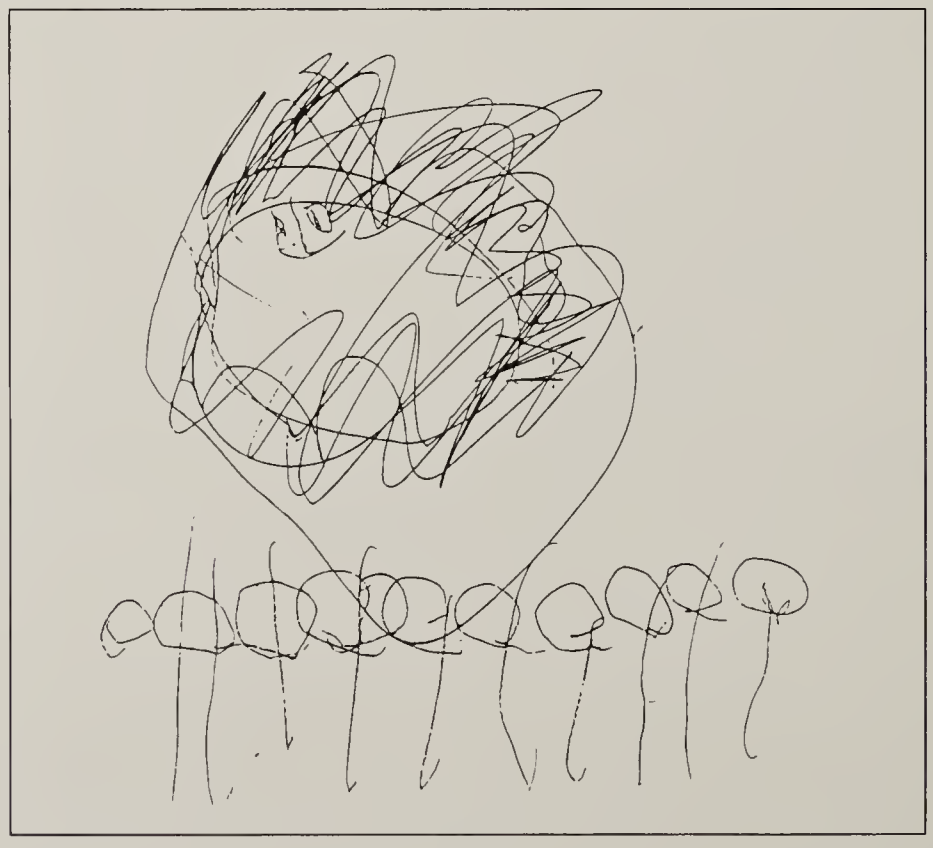
Some of the objects included in this handbook, such as drawing boards, can be constructed by using materials that are readily available. For example, the only tool necessary to produce a figure on a drawing board is a ballpoint pen, and, if a pen is not available, a nail will also do the job. For the vacuum-forming method, a machine method that produces plastic relief displays from a paper or wooden master, the necessary materials are a vacuum cleaner, a small heating unit, and some imagination. (Small units for use in this method

OPPOSITE PAGE: Peter, 9 years old, drew this man on a horse on a raised-line drawing board. He has never seen a horse, but he has felt many of them. He likes to ride.

are also available.) Your resources will help you decide how to produce relief material that is appropriate and effective for blind and visually impaired people.

This chapter includes 16 main sections, each of which discusses and illustrates a method of producing tangible graphic displays and the resulting displays. Eight can be done without machines: raised-line drawings, tactile-experience pictures, nonfigurative pictures, paper-on-paper buildup displays, buildup displays using additional materials, paper and tape maps and charts, embossed paper displays, and displays of movable parts. Six of the methods included involve machine production and produce plastic relief copies (the advantage of which is that the displays can be mass produced; also, plastic is durable, can withstand much wear, and can be used outdoors, for items such as maps): the vacuum-forming method, answer cards and pop sheets, wire and metal masters, the microcapsule paper process, the electroforming process, and Nyloprint. There are also several methods of production with simple aids that are discussed under silk screening. And finally, there are computer graphics. Along the way, variations of these methods and the displays they produce will also be presented.

Note: As you read this book, it is helpful to keep in mind that variation in height is the trait of a relief display that gives the greatest amount of information to the blind or visually impaired reader. Low profile or low relief is opposed to high profile or high relief. High relief can be used for other purposes but is not



The sun going down behind the trees. Drawn by Peter, age 9, on a raised-line drawing board. He used a standard ballpoint pen.

suitable for schoolbooks in braille or other conventional material for blind readers because of its tendency to collapse when touched. Therefore, techniques discussed in this book are to be done with a low profile in mind. In general, it is not advisable to exceed a profile of 1/4 in. (6 mm). In cases in which a high profile is used, the materials are usually filled in with some kind of material on the back side so that the high-relief forms will not collapse when used by blind readers.

RAISED-LINE DRAWING BOARDS

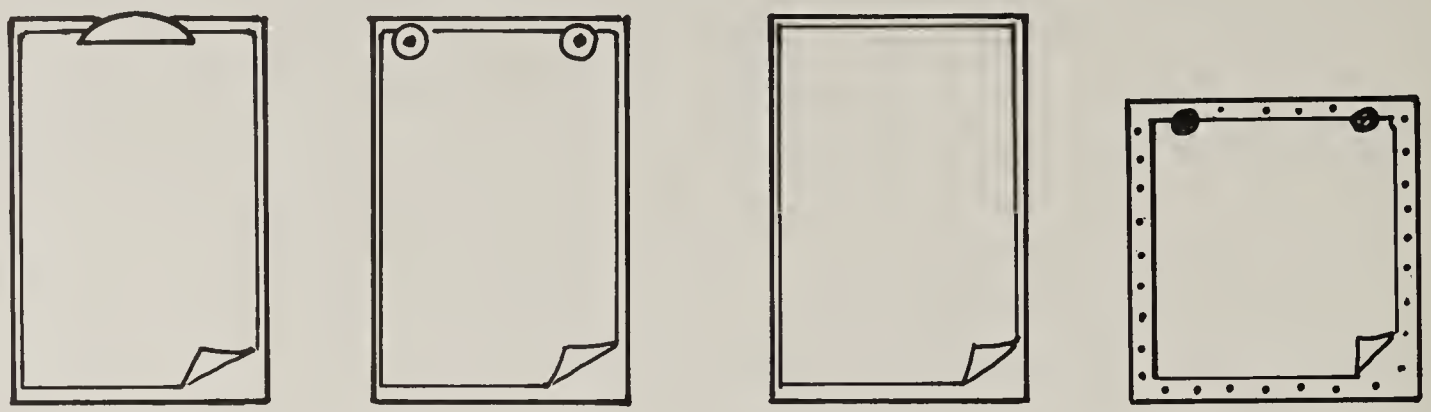
The raised-line drawing board is an important, if not the most important, graphic tool for visually impaired children. They can use it to express themselves to you, and you can explain things to them on it graphically. The use of the board trains the child in the comprehension of pictures, a necessity throughout his or her education, and it can be an effective tool to help increase the child's self-confidence in a world where all children draw at one time or another, especially if the child is in an integrated school setting.

Each country seems to have its own design of the reusable drawing board. They all do the same job, and they all consist basically of a thin rubber sheet fastened to a firm backing of cardboard, plastic, or wood. This pad is covered by a removable and disposable film of plastic, fastened to the board by clamps or slipped over the board like a muff.

In the muff system used in Sweden, two thin sheets of plastic are seam-welded along the two longest parallel edges. The drawing board slips between these two sheets. This construction makes it easy for a child to change the muff sheet independently. Instructions or comments can be written directly on the drawing since the muff can be used in a braillewriter or with a slate or stylus. The plastic backing is sturdy enough to allow page holes to be punched in the muff so that it may be kept in a loose-leaf folder.

A ballpoint pen, pencil, or stylus produces a raised line when drawn over the plastic film. The drawing technique used is limited to simple linear diagrams. Errors cannot be erased.

In some common drawing boards, a plastic sheet is fastened to a rubber-clad board by a clamp, screws, or double-sided tape (see A, B, and C). Some boards are made with holes on all sides so that a ruler or a protractor, equipped with

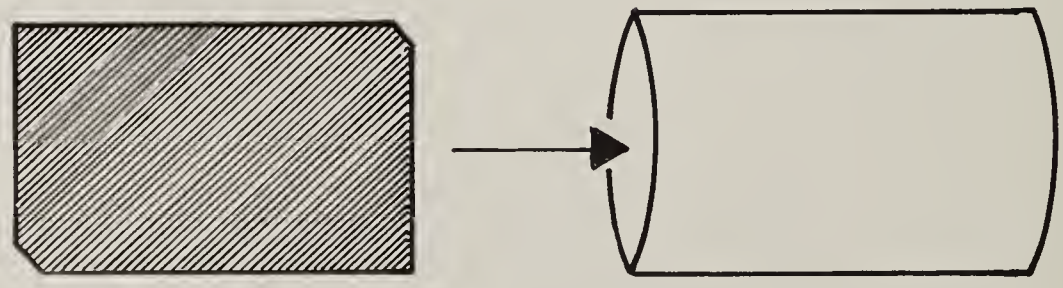


A. B. C. D.

two pegs to fit into the holes, will remain in place (see D). The loose bottom edge of the plastic sheet on these boards has presented a problem. The plastic does not remain in one place. It follows the user's arm or hand and has a tendency to roll up when caught on a sleeve.

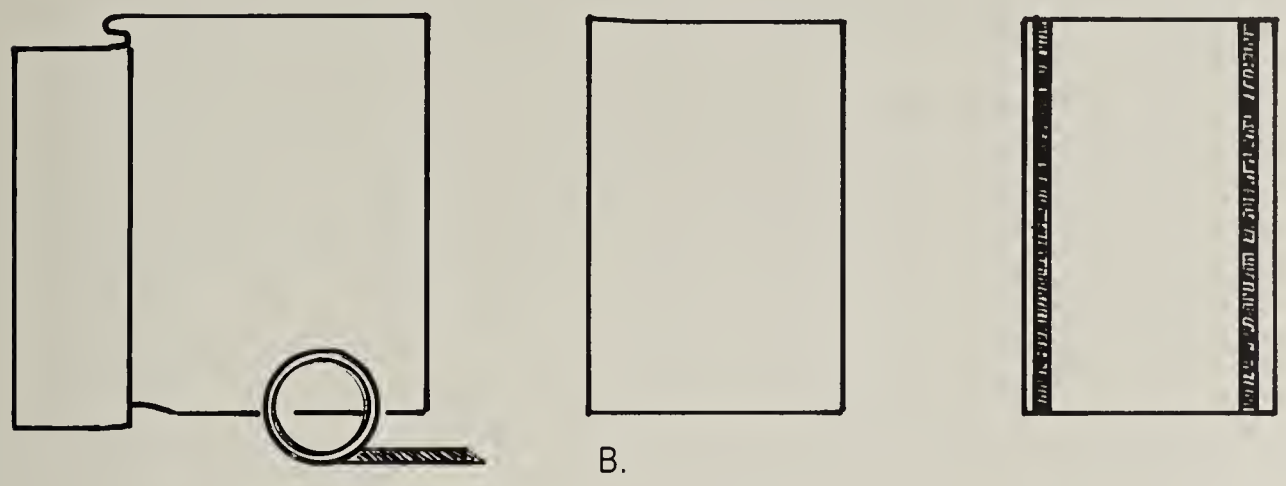
The following are solutions used in different countries:

- The Danes have added a strip of double-sided tape to the lower edge of the board.
- The Japanese sprinkle a few drops of water between the board and the plastic sheet; this process causes the two to adhere to each other for a short period.
- The Swedish use the muff system, in which the board slips into a plastic muff that is open at both ends and thus eliminates the loose bottom edge (see A).



A.

A muff can also be made by folding plastic around a sheet of braille paper and taping it into place on the reverse side of the paper (see B). The advantage of this system is that teachers can write notes in ink on the braille paper. The braille paper and plastic sheet can be used in a braillewriter or with a slate and stylus. The disadvantage is that taping the plastic to the braille paper requires manual labor, while the seam welding of the all-plastic muff can be done on a machine.



B.

The drawing board and plastic sheet are ideal for instant explanations of routes, objects, formulas, and diagrams. They are excellent for use as a blackboard substitute during class instructions when the blind student is integrated into a class of sighted students.

Most drawing boards are available in the standard A4 size, 8.27 in. by 11.69 in. (21 cm by 29.7 cm). (See Appendix 1 for more on standard paper sizes.) In Sweden, they are also available in the A3 size, 11.69 in. by 16.54 in. (29.7 cm by 42 cm) and in the A5 size, 5.83 in. by 8.27 in. (14.8 cm by 21 cm). The A5 board is pocket size and is useful for explaining mobility problems in the field. It is constructed with a firmer backing than the other boards, which enables it to be used "free hand," without resting it on a table. All three sizes are available in Sweden from RPH-SYN, the National Center for Educational Aids for the Blind in Sweden (see "Sources of Materials and Equipment," Appendix 3 for the address). Drawing boards and plastic drawing sheets, or rolls of sheeting to be cut to size, are available in most countries. The plastic used in Sweden for muffs is genotherm FA 46, transparent 10001 005, surface texture 8, thickness .002 in. (.040 mm). It is a polyvinyl chloride (PVC) plastic available from Svenska Hoechst (see Appendix 3 for the address).

TACTILE-EXPERIENCE PICTURES

Making tactile-experience pictures is a common technique and is perhaps the most widely used for displays for young children. It is based on materials that are familiar to readers and trains their ability to recognize different shapes and textures.

Pictures are constructed from many different materials

including wood, cloth, sandpaper, metal, fur, and plastics, which are glued or sewn to a cardboard backing. The materials should resemble tactilely the object portrayed. It is important that choice of materials be governed by feel, not by sight, although it is wise to keep in mind that people with low vision will also use your pictures, a fact that may affect your choice of materials.

These pictures should not be reproduced in a vacuum-forming machine (see "The Vacuum-Forming Method" later in this chapter), which would destroy the minute differences in density, sensitivity to temperatures, and the variety in textured surfaces by turning them into plastic copies. Plastic copies are excellent when reproductions are necessary, but nothing can take the place of the feel of actual materials.

Instructions pertaining to perspective, size relationship, natural position, and reference line are the same for all pictures and are to be found in Chapter 4.

Points to Remember

Here are additional suggestions:

- To appeal to the sense of smell, add scratch-and-sniff disks or stickers. These stickers are coated with special inks that when scratched, give off a desired odor, such as pine, cinnamon, or orange. They can be bought in some stationery stores or ordered directly from publishing houses that use them in books for sighted children.
- To appeal to the sense of hearing, add sound buttons. These are often found on children's greeting cards. Remove them from the cards and use them in your display. Be sure to make a hole through the paper or cardboard behind the button to allow the sound to escape. Novelty shops and stationery stores may have such cards. Card manufacturers can give you addresses of sound-button suppliers. Japan is a leading producer of such items.
- To appeal to the reader's need for active participation, include items like windows, mailboxes, and purses that open; legs or arms that move; wheels that turn; holes to put fingers into or hands through; and zippers, buttons, snaps, and magnets that function.
- To make identification as easy as possible, keep the display

simple. Several uncomplicated pictures are better than one complicated one.

- Keep the elements in the display simple, without ornate decoration. Ask yourself if each element is really necessary—does it give enough information to warrant its inclusion?
- Be sure that the display can stand hard wear, since young children are not gentle in their examination of pictures. Glue the objects and textures to the background with hobby glue made especially for the material used. All items must be

"Reading" a tactile-experience picture.

In this active picture, the arm and hand holding the letter can be moved up to the letter slot. The letter slot cover, with the word *POST* can be opened. This picture was made many years ago, before I was aware of children's desire to feel two arms and two legs on human figures. (It is from *A Letter Means So Much*, P. K. Edman.)

kept under pressure after being glued to ensure maximum adhesion. A layer of plastic foam between the glued material and the added weight ensures that the same amount of pressure is distributed over the complete area, even if the surface is uneven.

- The adhesion of Con-Tact paper (the commercial self-adhesive paper covered with various textures) to a paper figure does not last as long as materials that are glued in place with hobby glue. Therefore, it is wise to fold the Con-Tact paper over the edge of the form, extending the paper a bit on the back side of the form. When the covered form is glued to the background, the glue will also hold the Con-Tact material securely in place.
- If possible, sew several stitches through objects in the picture to the backing of the display. Knot the thread after each stitch. A lost item could change a person's comprehension of the picture.
- If the picture is part of a book, cover all stitching on the back side of the cardboard with freezer or textile tape before covering the cardboard with a layer of paper. Doing so will prevent the stitching from wearing through the braille or picture on the following page.
- Some plastic materials melt when they come into contact with liquid glue. If you use such materials, attach them with double-sided tape or glue, which is sprayed from a pressurized can.

OPPOSITE PAGE: Pattern for a figure.

Special Techniques

To make figures:

- Draw a pattern. Trace it onto the cardboard. Keep the pattern to facilitate future repairs if parts of the picture wear out.
- Use several layers of cardboard to build up the head, arms, and legs where it will give the best effect. Build up the figure as you would a topographical map. The point farthest from sight is only one thickness of cardboard. The part closest to you may be made of several layers of cardboard.

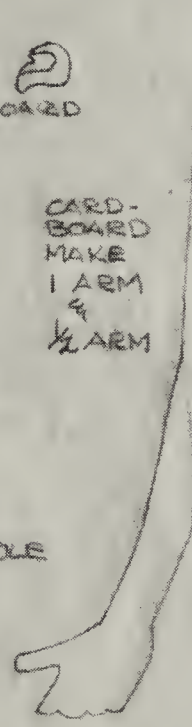
  The rear view of a figure should have a body of one thickness of cardboard with a raised seat made with an added thickness of cardboard. Thus the rear view of a figure

PATTERN - POLICE BOOK

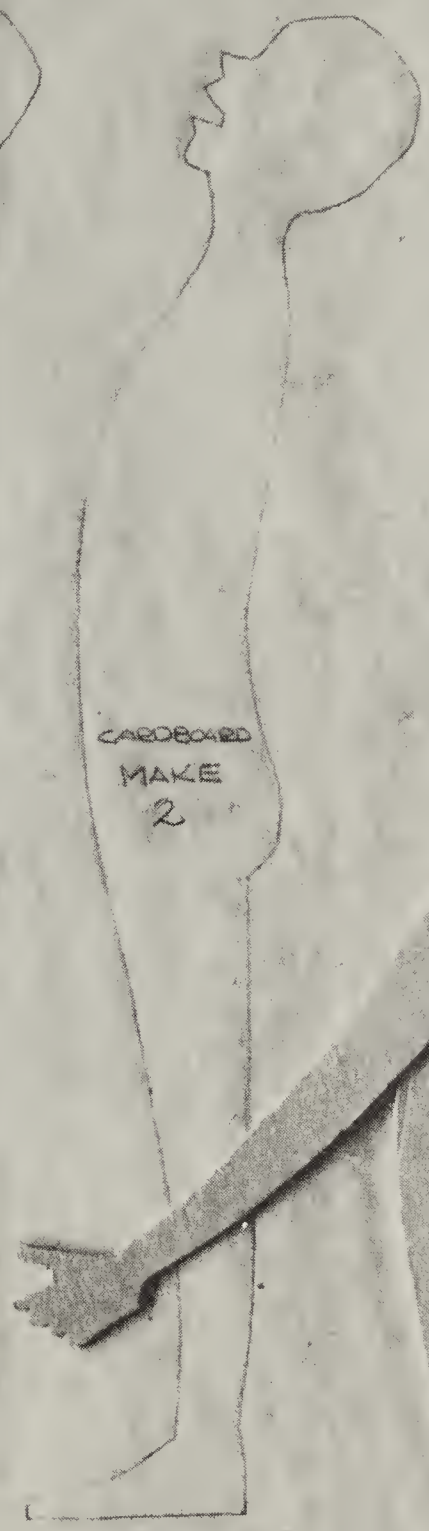
EYE = SMALLEST BEAD

CARDBOARD
MAKE 1

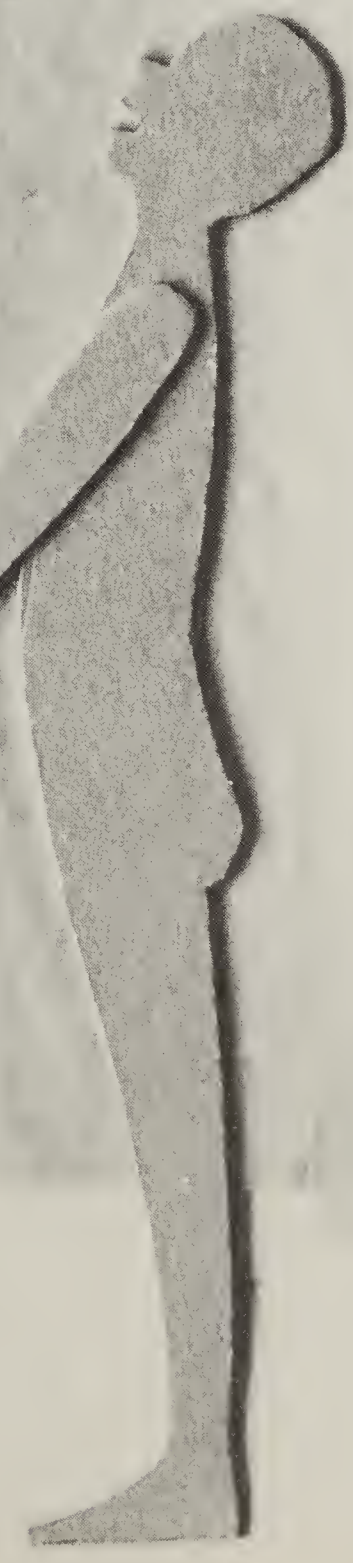
CARDBOARD



CARD-
BOARD
MAKE
1 ARM
&
½ ARM



CARDBOARD
MAKE
2



① CUT 2 BODIES
TAPE 1 NECK
TAPE BOTH LEGS

PUT SOCKS & SHOES
ON BOTH LEGS

GLUE BOTH BODIES TOGETHER

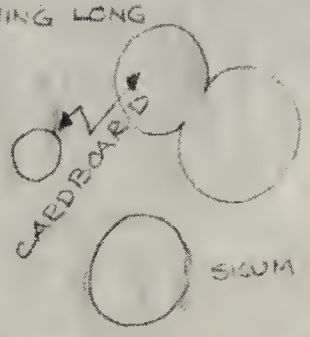
② CUT HEAD
COVER WITH TAPE
MAKE EYE HOLE
SHAVE EXTRA PAPER FR. EYE HOLE
GLUE HEAD TO BODY
SEW IN EYE AND EYEBROW
MOUNT BEAR IN PLACE

③ CUT HAIR & GLUE ON HEAD

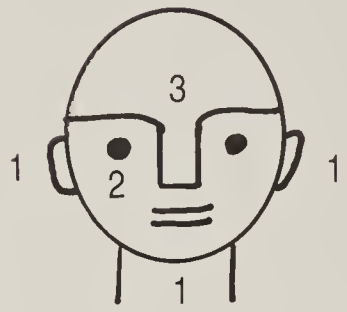
④ DRESS BODY

⑤ CUT ARM
COVER WITH TAPE - LEAVING LONG
END BEYOND FINGERS
BACK END
WITH S. PAPER
UNTIL BEAR IS
MOUNTED

CUT ½ ARM
A BIT SMALLER
AND GLUE UNDER
ARM.



⑥ COVER ARM WITH
SLEEVE -
GLUE ARM TO BODY



is easily distinguishable from the front view, the latter having a raised head, stomach, feet, and breasts (if it is a woman). The figure in profile should have one layer of cardboard for the complete figure and a second layer for the body, right leg, right arm, and head (not the neck). The third layer should cover the right arm, and perhaps the right leg and right ear.

- To simulate skin, adhesive tape is often the right color and texture. Cover the surface on the lowest layer of the figure—first, tape the neck and ears, second, the head, and third, the nose and forehead, as shown here.

  Attach tape to a cardboard form. Leave about 0.2-0.3 in. (5-8 mm) of tape protruding beyond the edge of the cardboard. Trim away the excess tape and fold the remainder tightly over the edge of the form.

  When fastening tape to the back of the curved edge of a figure, such as the face, arms, or legs, make several small incisions along the edge of the tape, cutting *almost* to the edge of the cardboard. This will enable the tape to be molded to the curved form without leaving irregular edges. If tape is cut all the way into the cardboard edge it will leave an irregular edge.

  When covering the hands with tape, extend the tape beyond the fingertips, then fold the tape under the fingers far under the hand on the back. This technique will prevent the fingers from splitting and falling off after long use of the picture or book.
- To simulate hair, use scraps of various types of animal or synthetic fur. Cut fur on the skin side, using a razor blade or scalpel. Cut through the skin but do not cut the hairs themselves. Be sure that the direction of the fur coincides with the desired direction of the figure's hair and that the pattern is reversed when you are cutting. Glue the hair onto the head and shape it with a scissors.
- To simulate eyes, submerge small round-headed pins or beads into holes punched into the surface layer of a cardboard head. Shave off the excess cardboard, which has been formed by punching these eyeholes, from the back side of the head so that it will not increase the thickness of the cardboard head. Sew beads into place through the second layer of cardboard.

Figure in profile.

- For lips, sew a rubber band through the head with a darning needle and fasten it on the reverse side of the head or page. For teeth, use melon seeds, flower seeds, or rice, for example.
- To make clothing, fold the material around the edges of the forms and fasten it on the back. This will help prevent frayed edges. Because the body of a cardboard figure often resembles the human body, clothes should not fit tightly around the arms or ankles and should blouse naturally at the waist. If possible, attach material only on the reverse side of the form. This gives the clothing a natural—not static—

feeling and allows the form of the body to be felt through the material. Figures may be padded with foam rubber before being dressed to add to their realistic feeling. (Foam rubber often melts when glued; fasten it in place with double-sided tape.) Remember that using the same clothing and hairstyle on a particular figure throughout a book facilitates recognition. An additional hint: women's and men's worn-out watch straps work well as belts.

- For color and texture remember that if a product feels ideal for a certain use, be sure that it is also the right color. Although color is of no concern to blind readers, you should take into consideration that low vision or sighted children may also look at these pictures. Sandpaper is one of the most useful textures available. It comes in many different grades of coarseness. For sidewalks, use 00 grade; for stuccoed buildings, grade 7; for beaches, sand paths, and walks, grade 3; and for asphalt, a fine-grain black sandpaper that is meant to be used wet when sanding.

To make animals:

- If you have it, you can use fur to make the body. The nap should be cut so that the fur runs back from the animal's head. Reverse the pattern and cut the fur skin side up. Trim the fur on the face and feet of the animal for easier reader recognition.
- For claws, use fine covered electrical wire. Peel off the coating if desired or shave off the back side of the coating to make a better gluing surface.
- For whiskers, lightweight twisted wire, waxed buttonhole thread, or hair from a horse's mane all work well.

For the text:

- Plan to put it on the same page as the picture if you are making a book. Often words—or even a small word—at the top of the page lead the reader into the picture and explain it.
- Before putting your display together, type the braille text where you want it on the page—above the illustration, below it, or in both places. Fasten the braille paper to the

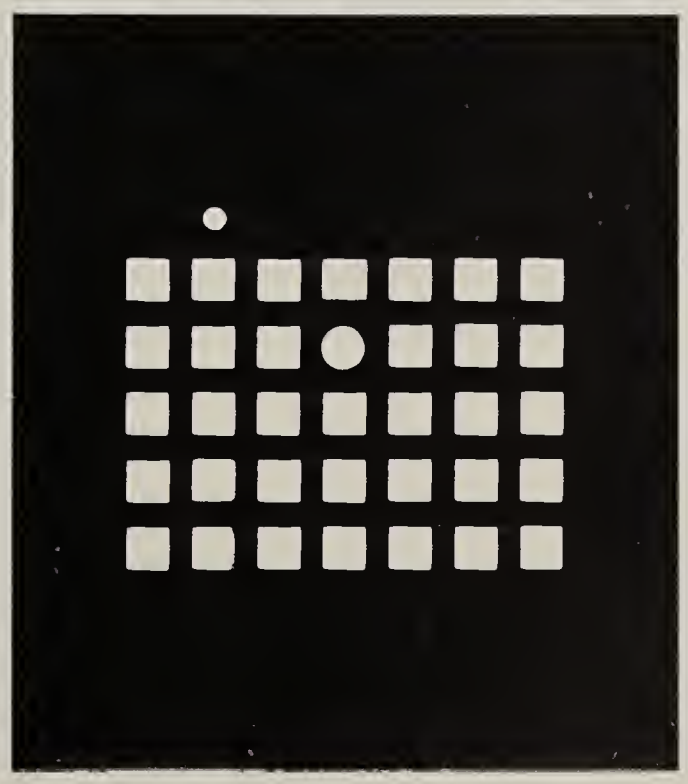
cardboard backing with double-sided tape or glue. Mount the parts of the picture on the braille paper. This system eliminates the unnecessary addition of extra labels or strips of braille glued onto the page that may become an integral part of the picture and cause reader confusion.

When making book covers, remember that a tactile-experience book should be put into a loose-leaf binder. This allows for easy repair or replacement of pages. The concept of the picture may change drastically if a part of it is lost. Knowledge gained from the picture is only as extensive as that gleaned by the reader's fingers as they scan the relief.

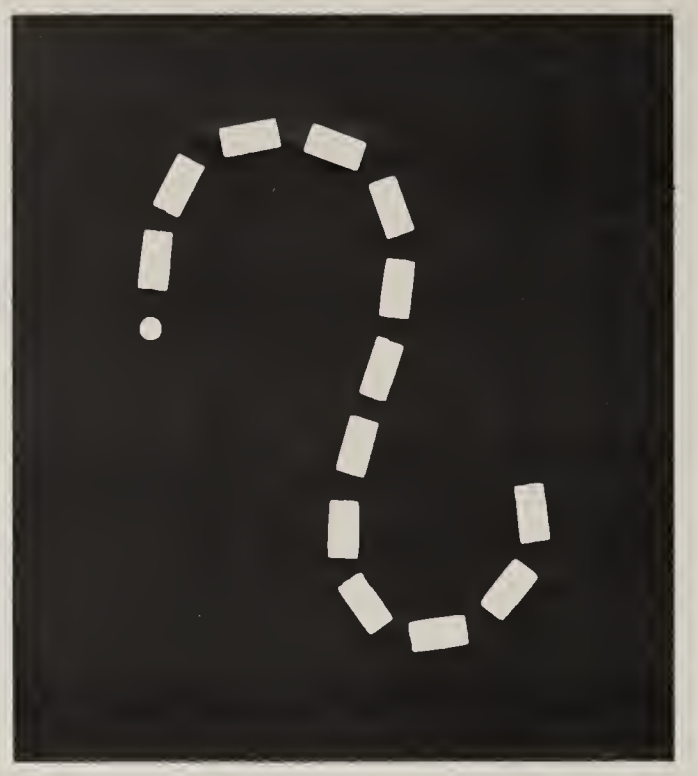
NONFIGURATIVE PICTURES

Nonfigurative pictures are made up of nonrealistic shapes—a circle may indicate a person, for example, or an irregular form a house. The pictures may be a tactile experience in themselves, but this experience cannot be related to the reader's knowledge of things in the surrounding world.

The advantage of tactile-experience pictures versus nonfigurative pictures is a controversial topic. Many people think that young blind readers have great difficulty understanding figurative pictures, especially if the pictures are to be felt without the help of sighted people, and consequently, they have used symbols of things that the child recognizes—a



These pages (SEE THIS AND FOLLOWING PAGE) from *Roly Goes Exploring* by Philip Newth show two nonfigurative pictures. Roly is represented as a small circle. The various forms, consisting of holes in the page, are cut or punched out of heavy paper. The book is made for both sighted and blind children and has been very well accepted by both.



circle, square, triangle, or any other form that will not change physically throughout the book or series of pictures.

Philip Newth, writer, illustrator, and producer of a number of nonfigurative books for visually impaired children, believes that a flower, a tree, a house, or a radiant sun can ook beautiful in a relief display but feel completely meaningless (personal communications, 1960-69). A sighted child will have no trouble understanding the stylized forms presented, but a blind child will be lost in this relief jungle. The classic picture of a house—a slanted roof, two windows, and a door—quickly produces in a sighted child an association with many different houses. But what does this picture do for a blind child, who has never physically experienced the proportions of a house as a whole and who, at best, can barely put together his or her individual experiences of it, one at a time, to make the complete form?

Naturally, blind children can learn to recognize a house if they often come in contact with pictures of a house. But change the form or position of the house and the young blind child may have difficulty, because the symbol representing the house is not the same. When making nonfigurative pictures, keep this problem in mind and try to use those forms that blind children recognize.

Abstract forms that have no connection with any preconceived, sighted symbols can whet the imagination of both blind and sighted children. The children can associate with the forms in their own way. The illustrations shown here from *What's*

That? by Virginia Allen Jensen and Dorcas Woodbury Haller were made with this principle in mind. They are printed in foaming ink on an offset press. The relief is pleasant to touch and enables the reader to recognize the textures independently.

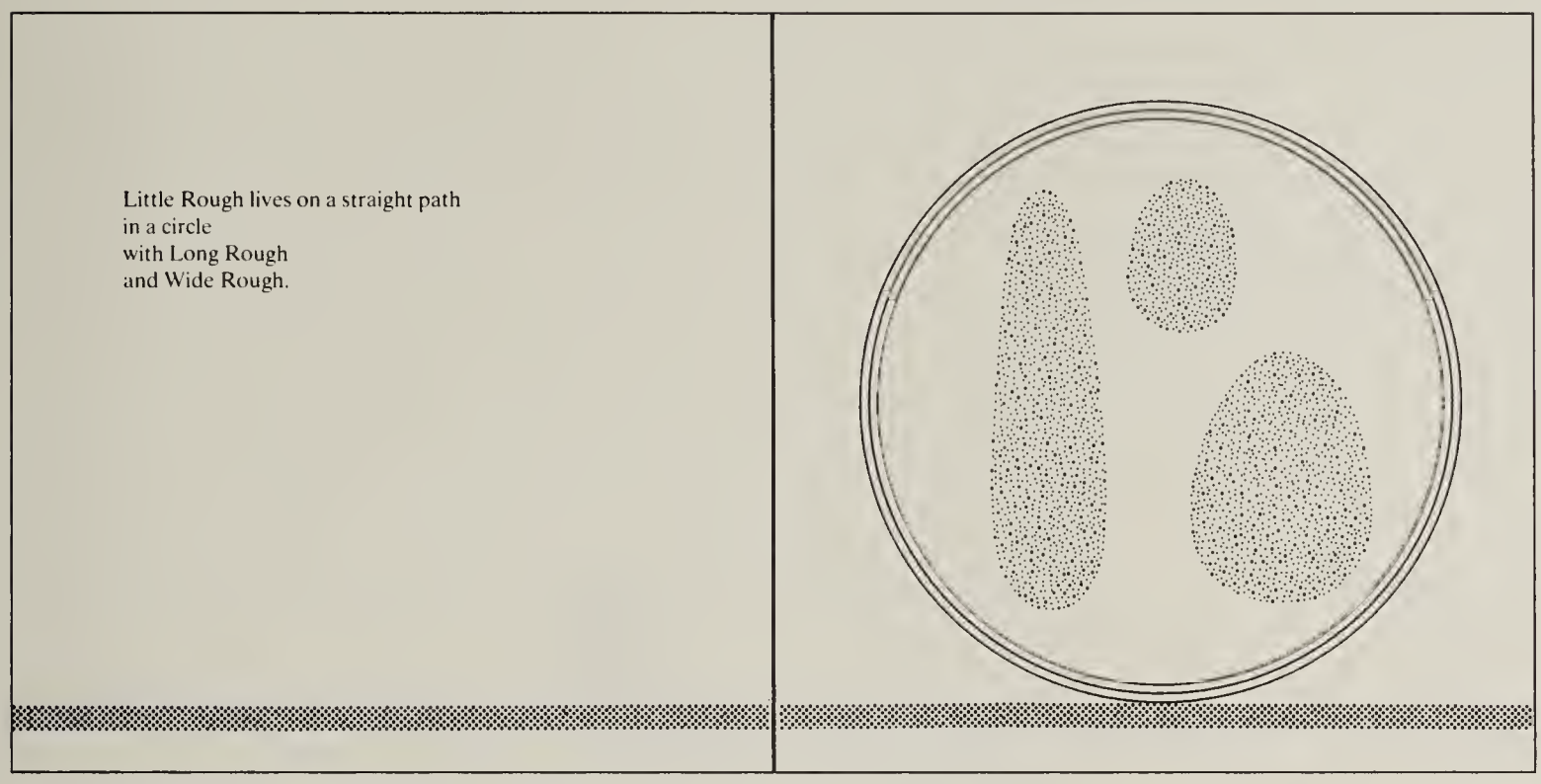


Illustration of the Rough family, from *What's That?* by Virginia Allen Jensen and Dorcas Woodbury Haller. Little Rough, Long Rough, and Wide Rough are inside their circle. The word "Rough" is used as both a name and a texture.

What's That? is intended for preschool children who are at least 2 to 3 years old. Jensen (personal communications, 1978-80) made several interesting observations about the creation of the book:

> Originally we called Wide Rough "Mamma Rough" and Long Rough "Pappa Rough," but since the book was abstract throughout, except for what the little figures think and do, we decided not to identify the sex of any of the figures. Therefore, we avoided using the word "he" or "she" entirely, and if the children wanted to, they themselves could call them "he" or "she." This gave the children additional possibilities for identification. So we named the big figures Stout Rough and Tall Rough, but the blind children objected strongly. The figures couldn't be stout or tall because they were flat on the page! We then realized that the children were thinking 'flat' and that up and down on the page were not the top and bottom of the page. We who are accustomed to looking at a picture like this see the straight path as the ground and the circle standing on the ground like a hoop; but the blind child reads the page as we would a map. "Up" for the blind child is up *from* the page, just as the word "tall" would indicate up *from*.

We have learned to interpret a line that runs across a page parallel to the bottom edge of the paper as the horizon. This is a convention that we take for granted. The blind child, however, who is first learning to read pictures, is not aware of this convention and sees the line simply as a line across the page.

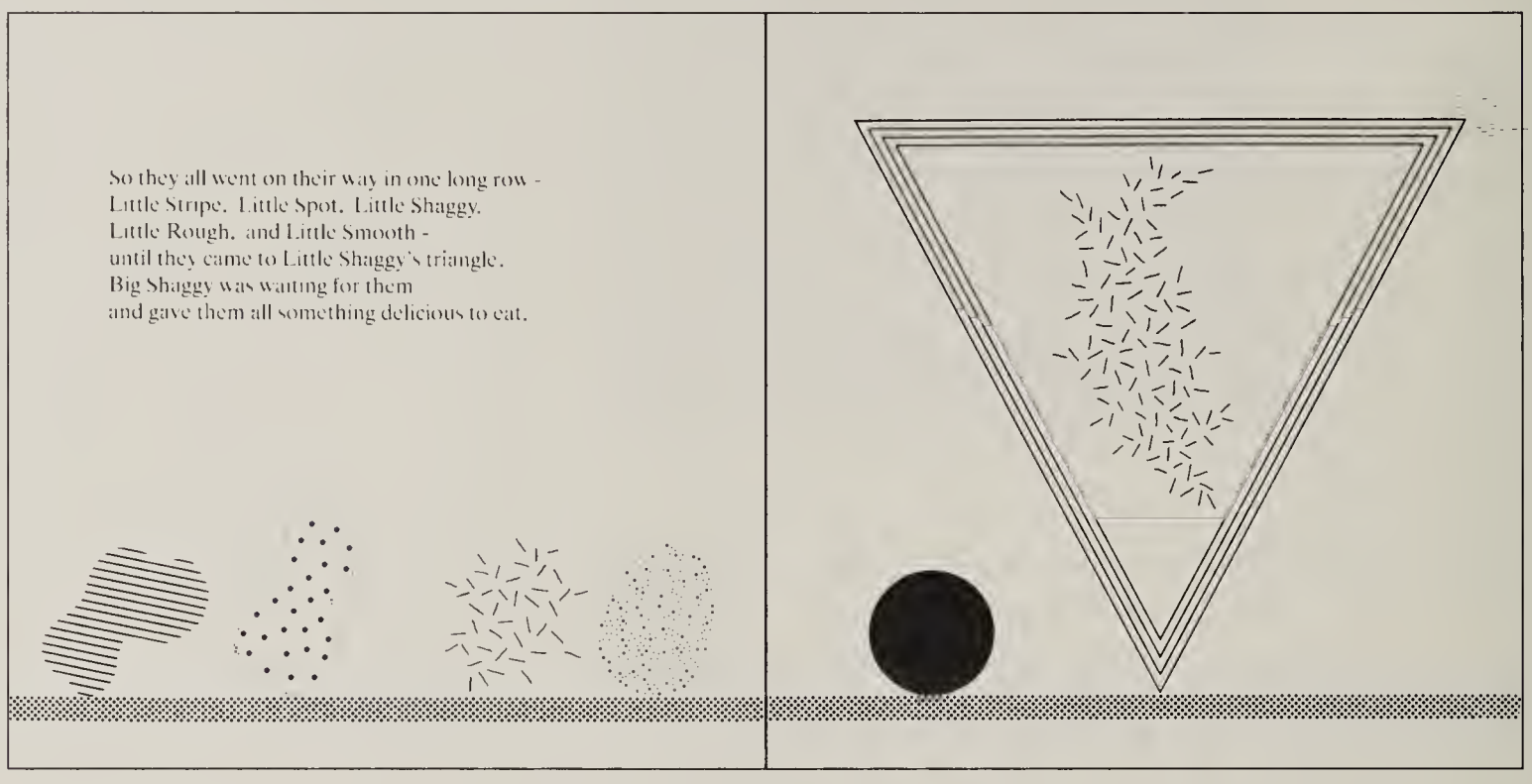

So they all went on their way in one long row -
Little Stripe, Little Spot, Little Shaggy,
Little Rough, and Little Smooth -
until they came to Little Shaggy's triangle.
Big Shaggy was waiting for them
and gave them all something delicious to eat.

Illustration of the Little figures from *What's That?* Little Stripe, Little Spot, Little Shaggy, Little Rough, and Little Smooth are all on their way to the Shaggy family's triangle.

The illustrations from *What's That?* shown here are an example of how text and pictures must work together. As Jensen (personal communications, 1978-80) further noted:

> Here you see the Little figures on their way to the Shaggy family's triangle. For sighted children we would be tempted to say, "They went on their way, first Little Smooth, then Little Rough, Little Shaggy, Little Spot and Little Stripe." According to the conventions of the sighted, Little Smooth is indeed first in line, but what does the blind child feel first? He is learning to read the pictures in this book by following the paths (the lines) from left to right; so he feels Little Stripe first. Then Little Spot, Little Shaggy, and so on.
>
> So as not to confuse the blind and the sighted child reading the book together, each with his own idea of what comes first, we avoided using the word "first" at all, and said simply, "They went on their way in one long row."

Children's positive reaction to *Roly Goes Exploring and What's That?* has been far beyond expectations, proving that a promising future exists for this type of picture for both blind and sighted children. This field presents an exciting challenge and deserves more research and experimentation.

PAPER-ON-PAPER BUILDUP DISPLAYS

Paper-on-paper buildup displays are made by gluing layers of paper or cardboard forms to a paper or cardboard background. The forms are cut out with a scissors, scalpel, or hobby knife or are stamped out with a hand punch. Sandpaper of all grades is often used in this type of display. *Note*: The description that follows for paper-on-paper buildup displays and for many other techniques included in this chapter—other buildup displays, paper and tape maps and charts, embossed paper displays, displays with movable parts, answer cards and pop sheets, and wire and metal masters—is based on the possibility that you will be using your material as a relief master. In such cases, the master is an original display from which duplicate copies can be made in a vacuum-forming machine. The information presented here is pertinent to production of a single copy or a master that will form the basis of several

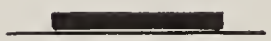
This paper-on-paper buildup is made with several layers of braille paper.

copies. Attending to it will help lengthen the life of your display as well as increase the comprehension of readers who use it.

When selecting cardboard, try to find the type that is made up of interwoven fibers, as opposed to cardboard made up of layers of paper. The interwoven fibers hold the cardboard together—edges will not split or splay and areas of the cardboard will not peel off from the display. If used in a vacuum-forming machine, there is a risk that layered cardboard may split and parts of the display may fasten in the plastic copy.

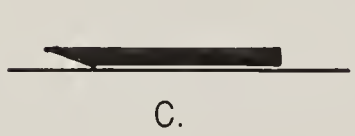
Techniques to Follow

Here are some suggestions:



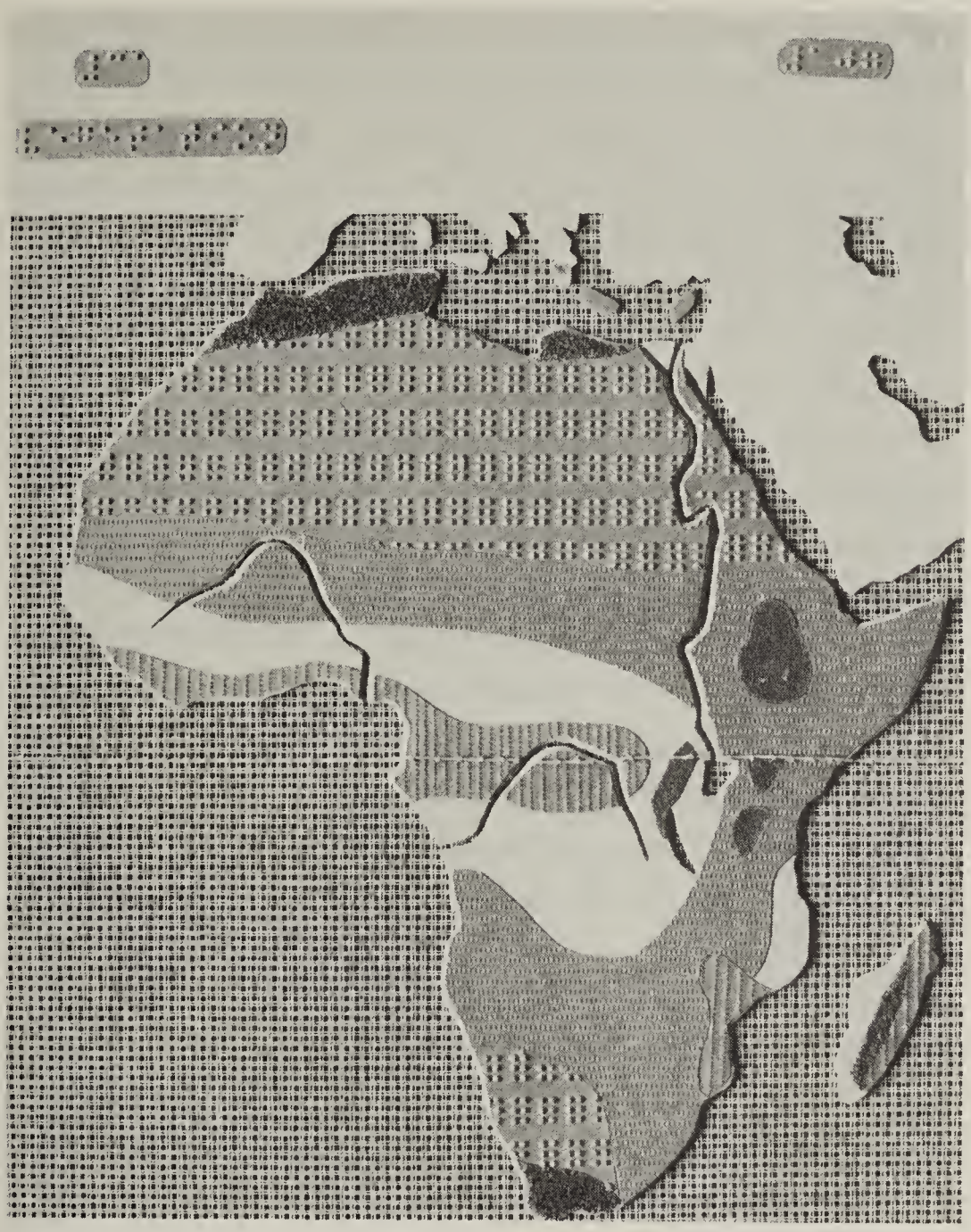
A.

B.



C.

- It is important that the edges of the forms used in the display are cut sharply at a right angle or an obtuse angle (see A and B). Never undercut the shape at an acute angle (see C). An undercut edge is formed when material is cut away from the underside of an object so as to leave an overhanging portion. Such edges are easily torn if the display is heavily used.
- Colored papers or cardboard can be misleading when you are making a master. They may give an excellent visual impression but not work tactilely. Can you feel individual parts of the objects or animals in your display? You may find it easier to construct a display using only white paper and cardboard.
- Paper cut with pinking shears, or shears with a saw-toothed edge for the blades for making a zigzag cut, can be used in many situations. The zigzag strips of paper can be used as single strips or serrated edges can be glued so they overlap and form a large textured area.
- Be careful when gluing to the background braille paper that has been embossed with braille dots or a spur wheel (see "Embossed Paper Displays" in this chapter). The glue may soften the paper so much that the relief areas lose their character. It is advisable to treat all braille-printed paper that is to be glued with a thin coating of shellac, sprayed or brushed over the back of the paper, or with putty, spread thinly with a spatula over the back of the texture. The putty treatment does not change the feel of the paper, whereas the shellac may make the dots feel sharper.



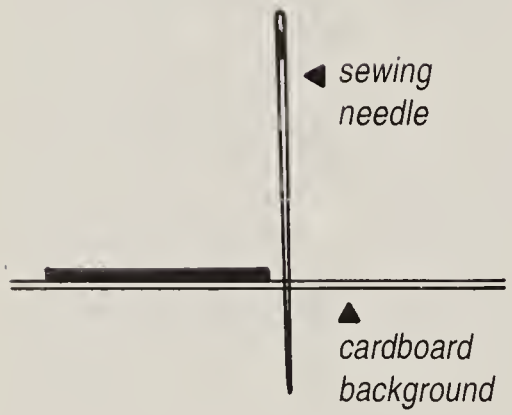
A simple, inexpensive map master, created by using various textures made on a braillewriter or with a slate and stylus. For such a display, the textured braille paper is glued to a cardboard form, which is then mounted on embroidery canvas. Since the printed textures have the same level of elevation on this map, namely, the braille dot, it was necessary for each texture to be completely different from its neighbor so that it could be easily understood by the reader.

- It is important to keep in mind that the life span of a cardboard or paper master is limited and depends on the amount of use the original display will be given, or the number of copies that are made from it if it is to be used in the vacuum-forming process. Keeping all display patterns will make it easier to remake and replace worn-out parts on your original display. (Additional suggestions for the paper buildup technique appear in the next section.)

Mass Production

The following are points to keep in mind when making a paper buildup display for mass production in the vacuum-forming process:

- An undercut edge will not allow mass production of a display. The vacuum-formed plastic will creep under the



cardboard overhang and rip it off when the plastic copy is removed from the master.

- Special glue is recommended; the type used for wood, paper, leather, and plastic is available in hobby and hardware stores. Test the glue in a vacuum-forming machine before using it on your display. Some glues are not heat resistant; others have reduced adherence after repeated heating in the machine.
- Excess glue that creeps out along the edges of a glued form should be scraped away from the display before it dries. If this is not done the excess glue will show up in the plastic copies as an integral part of the picture or map.
- Air holes are necessary if the cardboard background is thick or compact (dense). These holes will help the vacuum process work properly over the entire surface of the display. The result will be a sharply defined plastic copy.
- Make holes as close to the relief areas as possible, using a fine needle. If the holes are close enough to the relief forms, and also small enough, they will not be felt in the plastic copy.
- Air holes are often necessary in "tight" areas, such as small holes or sharp curves, irrespective of the density of the background material.
- Paint sensitive edges and small pieces such as fingers or islands on the original master, with shellac (often called Zapon lacquer). This will help protect the edges from splitting and the small pieces from becoming loose when the plastic copy is removed from the master. Be sure to test the shellac before applying it to the master. Some shellacs become sticky when heated and inhibit the removal of the plastic copy from the master. A dusting of talcum powder over the shellacked areas will help ease the removal of the plastic copy.

Papier-mâché is useful for making molded paper shapes. It is a tough, lightweight material that can be made from newspaper. It can be used for making a relief display that can be used in a vacuum-forming machine. Individual shapes or objects such as mountains or a map made with this material can be glued to a paper or cardboard background as part of a master, or the forms can be fitted with magnets and used on a

magnetic board (see "Magnetic-Board Diagrams" in this chapter).

To make papier-mâché, tear old newspapers into narrow strips about 1 in. (2.5 cm) wide, and tear these strips into pieces about 2 in. (5 cm) long. Cover the strips with hot water and let them stand for 24 hours (until mushy), stirring occasionally. When they are ready, lightly squeeze out excess moisture and add a thin paste of flour and water until the mixture is the consistency of an adhesive. Mold and allow to dry.

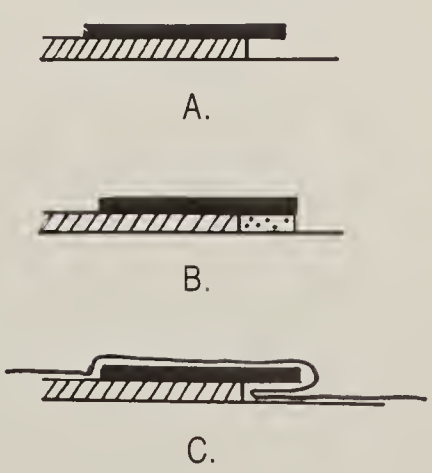
Low-relief displays that can be used in a braillewriter are made up of forms constructed from one or two layers of braille paper or one layer of sandpaper mounted on braille paper. This type of relief is useful in classroom work—in mathematics or physics, on relief maps, for example—when the student is required to make comments directly on the display sheet. These displays can be mass-produced. The braillewriter is capable of embossing braille characters on plastic that is .006 in. to .010 in. (.15 mm to .25 mm).

PAPER BUILDUP DISPLAYS USING ADDITIONAL MATERIALS

Paper buildup displays using additional materials are most often used to make a master. The principle is the same as that for the paper-on-paper buildup. However, this system involves making a display on a paper or cardboard base by using materials such as cardboard, wire, string, sandpaper, wood, leather, cloth, or clay, together or individually, to create shapes and textures in the vacuum-formed plastic copy.

Techniques and Materials

- No forms should be undercut. All edges should be perpendicular to the background or at an obtuse angle to it.
- There should be no free overhang of a surface area (see A). An overhang is easily damaged by continued use. Also, if the display is used in a vacuum-forming machine, the plastic sheeting used to make the copy will be baked on around the overhang (see B), and it will be impossible to remove the master from the copy. Fill in the area beneath the overhang (see C) to prevent this problem.

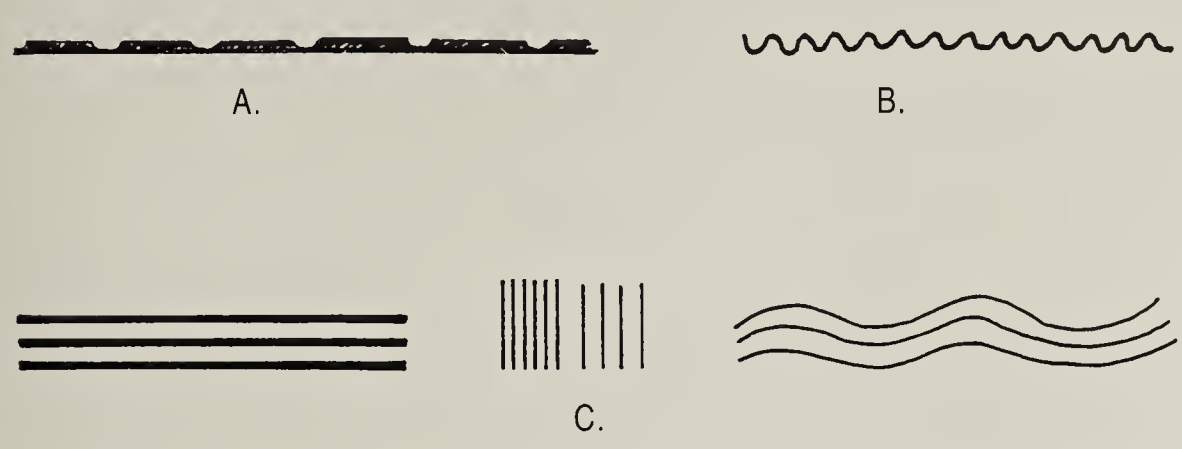


- Do not use materials that could melt at a low heat. Vacuum-forming machines usually have a temperature of around 392° F (200° C).

Various materials and techniques are involved in the making of paper buildup displays. They include wire, thread, and clay.

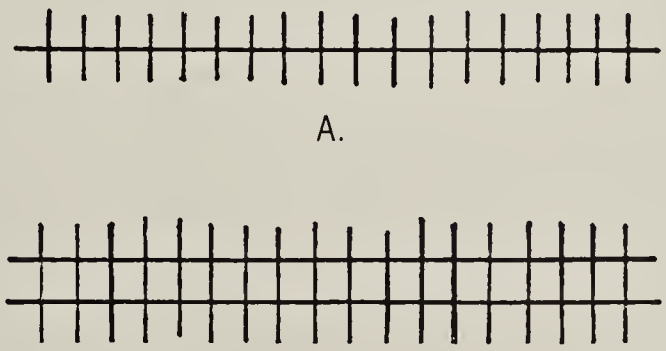
- When using wire, you can glue thin, pliable wire, such as picture-hanging wire, to the background material. (For structural variety, twist two or more wires together.) Pipe cleaners can also be used. To ensure that the wire stays in place and does not come unglued, sew it to the background in several places, knotting the thin threads on the back of the background material.
- Thin wires can also be threaded up through needle holes made in the background material. Glue them in place and thread them down through a needle hole again. Doing this will keep the ends of the wire from becoming loose through wear.
- File the ends of wires and coat them with shellac before gluing them to the background. This technique will prevent the wire or wire fibers from fastening onto the plastic copy.
- Various sizes of coated electrical wires are most useful and form well. However, since not all coating is heat resistant, test before using. If the coated wire is round with little area for adhesion to the background material, shave off a strip of coating to provide a greater gluing surface and to prevent the plastic copy from enveloping the wire. Sew the wire—especially the ends of the wire—to the background to ensure that it will not become unglued. This is particularly important. If the threads are too prominent around the wire, sew through the wire coating or between the wires if there are several in one strand.
- Solder, which often comes in coils, can be used as it is or can be rolled out and an imprint pressed into the semisoft material. Patterns can be made by hammering the side of a nail into the solder (see A). The pattern can be changed by changing the distance between depressions in the wire. Shapes can be made by weaving the solder between the teeth of a metal comb (see B). In addition, several wires side

by side or with a bit of space between them make a good texture for lines or areal, or textured, patterns (see C).



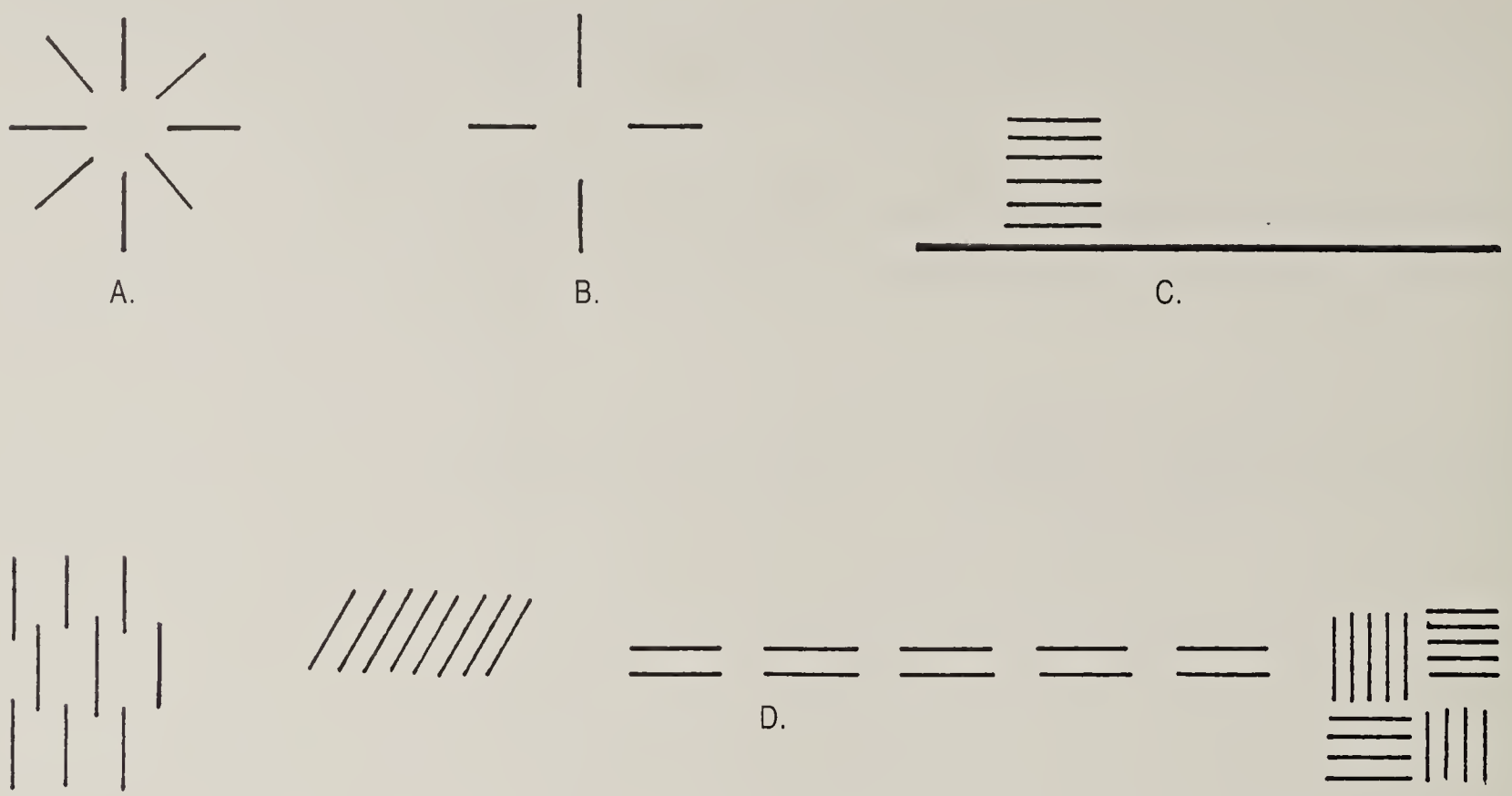
A. B. C.

- Wire or plastic screening cut with a scissors and held in place with glue or threads sewn into the background makes an excellent textured pattern. All such patterns spread over an area larger than several lines are called areal patterns. A similar effect is gained by using embroidery canvas. Be sure that the plastic screening is heat resistant and will not melt in the vacuum-forming machine. When you are gluing the screen to the background, do not use so much glue that the space between the cross sections becomes filled with it. In this case, the relief texture will be lost in the plastic copy. Narrow strips of screening can be used to indicate a fence (see A) or railroad track (see B).



A. B.

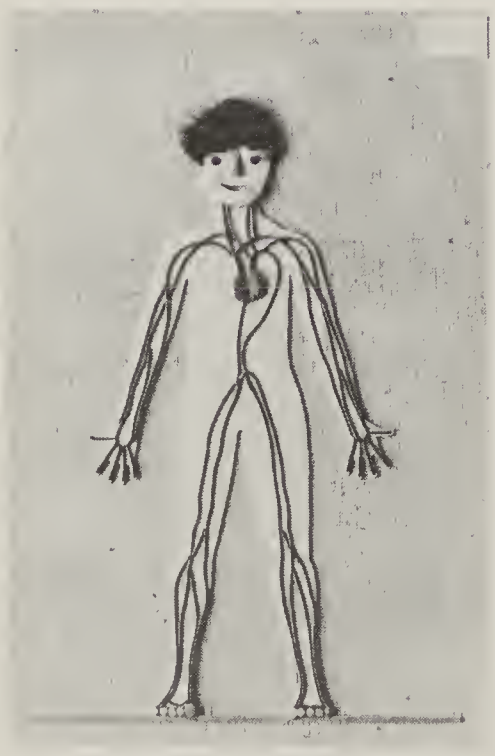
- Staples, when stamped into one of the layers of the relief display, stay in place and can be arranged in many different ways. The possibilities include arrangements that represent mountains or stars (see A and B on the next page), bars in a graph (see C), or area textures (see D). (These suggestions are not standard symbols of any kind.) There are several different sizes of staples on the market. By combining different sizes, you can make a wider variety of lines and textures.



Map-Making Kits and Their Materials

The Nottingham Map Making Kit was developed in the early 1970s by J.D. Armstrong and G.A. James for people who needed a standard set of mobility and orientation symbols and the materials with which to make map masters for mass reproduction of plastic-formed maps. However, the lead strips and some of the textures included in the kit could also be used in tactile displays other than maps, such as in depicting internal organs of the body or making electrical and mechanical diagrams.

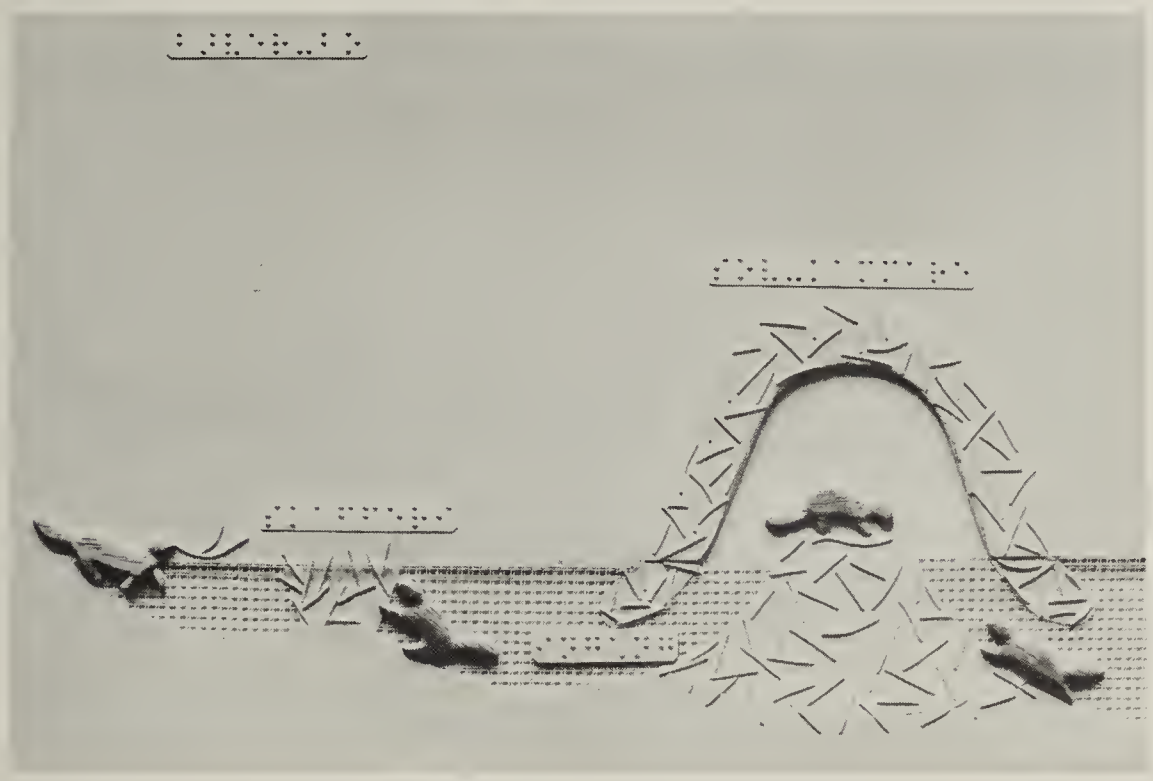
In 1989, the Nottingham Kit was replaced by the Euro-Town-Kit, produced by the Deutsche Blindenstudienanstalt in Marburg, Germany. The Euro-Town-Kit contains approximately the same type of map-making materials as the Nottingham Kit. There are several packages of soft solder strips of varying textures for line symbols, a package of point symbols of various sizes and forms, and sheets of areal textures. It also contains two guidebooks with symbols for use in town maps. One booklet describes the symbols in tactile form, the other repeats the meaning of the symbols in braille and inkprint. The application of the individual symbols is explained on a city map, on which all possible traffic and orientation situations occur. The kit, or parts of it, can be ordered from the Deutsche Blindenstudienanstalt (see "Sources of Materials and Equipment," Appendix 3 for address).



A simplified display using line symbols from the Nottingham Map Making Kit to explain the circulation of the blood. Two solder strips of different texture were used on top of a cardboard body form. The heart was made of balsa wood.

Embroidery Canvas and Bookbinders' Weave

Embroidery canvas is available in several different thicknesses. It is a useful texture to use when straight lines are desired, either as a background material or as a textured area. In Scandinavia, it is often used to indicate water in maps and other diagrams. Strips of fine-weave embroidery canvas can be cut to form railway tracks or boundaries on maps.



Embroidery canvas indicating water in a beaver dam display. The beavers are made of balsa wood. The sticks are preglued string.

Bookbinders' weave is a thin, gauzelike material that is available from bookbinders or from printing or publishing houses. The threads are irregular, both in thickness and in the character of the weave. This product is an excellent background for relief displays. It is less expensive than embroidery canvas. Because it is thinner than embroidery canvas, the imprint of the weave in a plastic copy is not as prominent.

Both weaves can be attached to a background surface with double-sided tape or with glue. The tape will not leave a mark on vacuum-formed plastic copies, although it is somewhat visible in the illustration on the previous page of the display made from Nottingham Map Making Kit materials. If it is not thinly applied to the background area, the glue may fill the weave. A spray glue may be easier to use in this case.

String and Thread

String and thread of various lengths and grades of coarseness may be used individually or in combination within the same

display. This technique is simple, economical, and effective, but it requires practice to use it with ease.

Pregluing

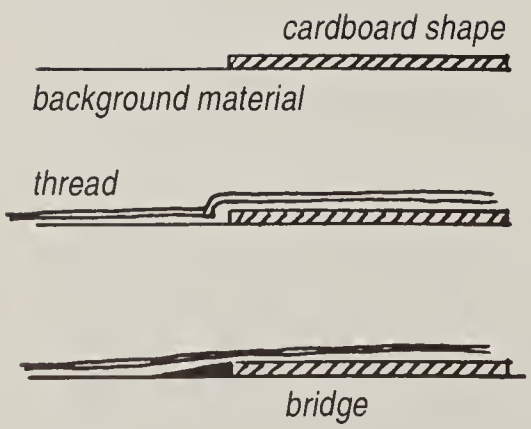
The string or thread should be preglued before it can be glued to a surface in the display. Use the following method:

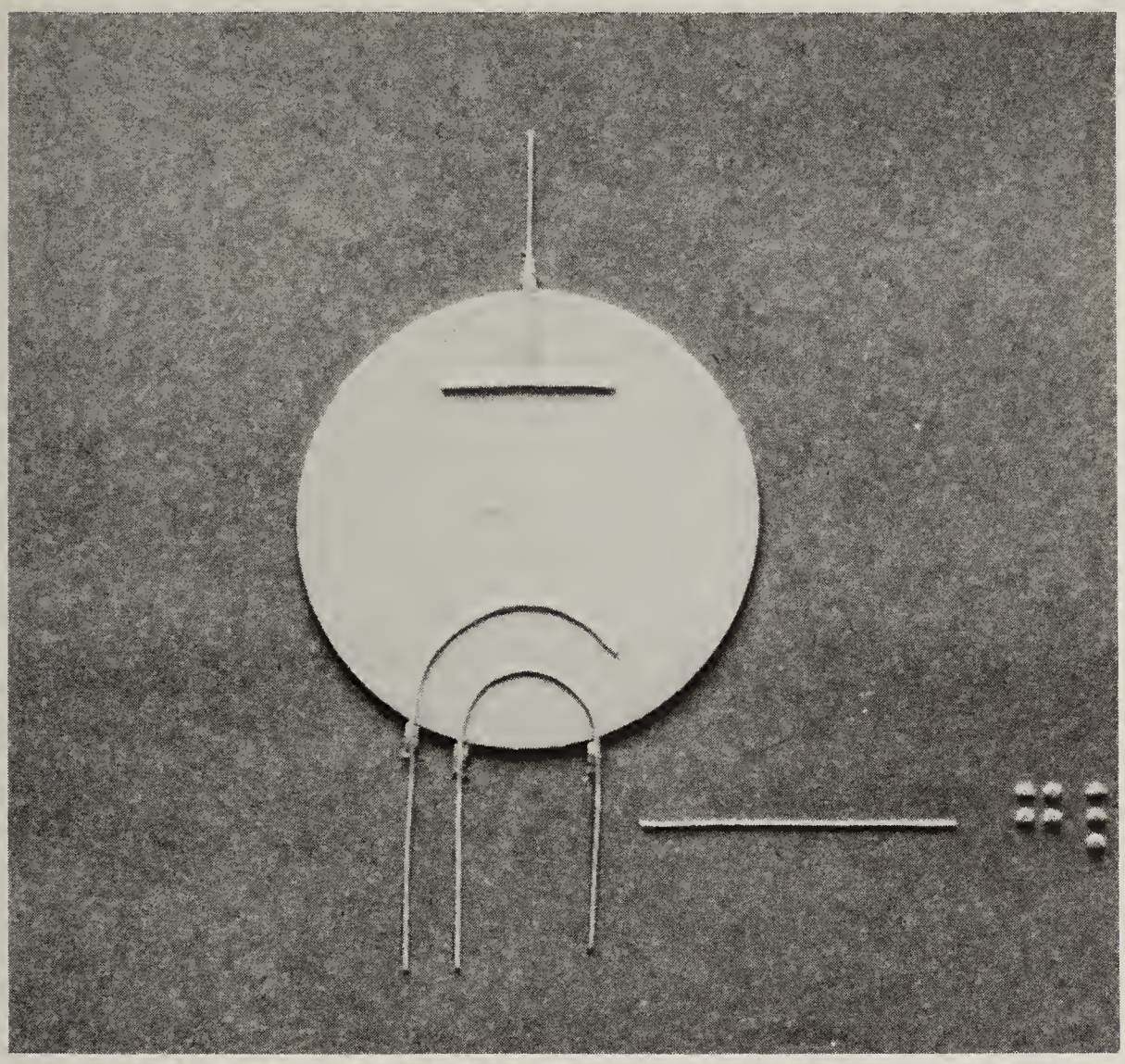
1. Pour a small amount of hobby glue (glue for paper, wood, material, leather, and so on) into a glass or small metal container that can be thrown away eventually. A paper cup may melt if the glue is left in it for any length of time.
2. Cut a length of string or thread. It is better to prepare too much than too little.
3. Submerge the string or thread in the glue, leaving a short end with which to pull it out of the container. Allow time for the string to absorb the glue.
4. Lift up the string or thread from the glue, drawing it between your forefinger and thumb. Squeeze out as much glue as possible.
5. Hang up the string or thread to dry.

Preglued string or thread will not absorb the second coating of glue when it is fastened to the paper. More glue is therefore left on the paper to create a stronger bond between the two materials.

Fastening

- To fasten string or thread in place on a display, first, glue an end down and hold it in place until it is securely fastened. Then apply glue to the rest of the string. Press down the remaining end of the string, allowing it to adhere to the background. Press the remaining string lightly into place. (This procedure is only a suggestion. You will soon be able to work out your own technique.)
- Thread or thin string that leads from one elevation to another may need a bridge between the two elevations. This bridge will eliminate a sudden rise from one level to the next and keep the feel of the thread smooth without an abrupt change in the flow of the thread (see the bridge depicted here). It is the thread that is important, not the point where it changes elevation. If the reader is forced to stop at this





Photograph of an electrical connection in which a thread bridge is used.

A master made of several layers of cardboard with an overlay of preglued string. The small black dots on the body of the porcupine are air holes, which are occasionally necessary to obtain a sharp plastic copy when the vacuum-forming process is used. The base line is sandpaper, and the claws are made of wire.

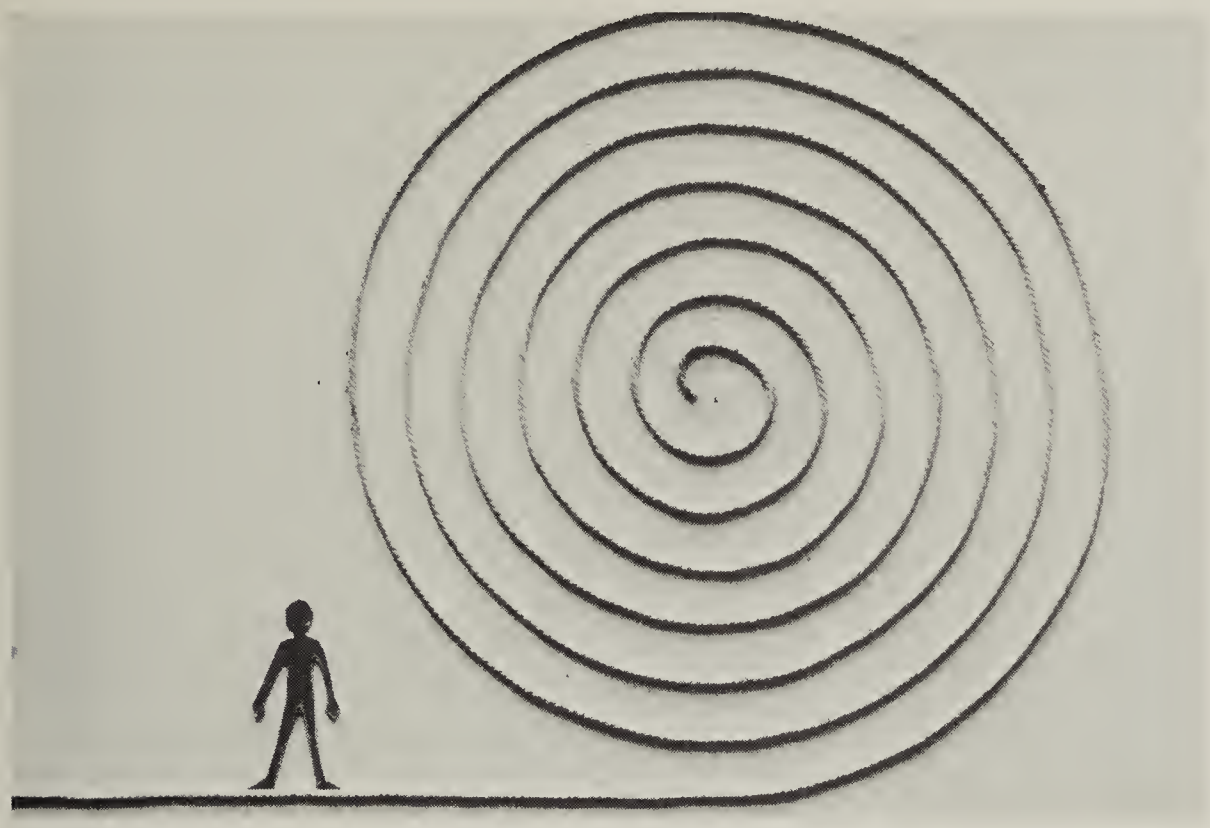
transitional point, he or she may misinterpret the meaning of the thread (the line). A bridge can be made from a narrow strip of cardboard or paper.

- When you are making a string spiral or curve, submerge the string in glue just before using it. Allow the string to dry a little bit, but it should not be stiff. The string can then be easily formed into curves, spirals, circles, and so on. When forming straight lines, you should preglue the string and allow it to dry completely before applying the second coating of glue.
- String spirals or other shapes that may form tight areas from which it is difficult to remove a vacuum-formed plastic sheet should be fastened to the background with additional thread. This procedure may be necessary only when using coarse string that forms a relatively high elevation.

  Glue the string to the background material. Sew thread through the background material, around the string, and back through the background again, fastening it on the back side. This technique is applicable only to displays that are mounted on cardboard or other rigid materials. If the background material is thin, such as paper, the knots in the thread will become bumps when the display is vacuum formed in plastic.
- String or coarse thread representing hair in a display should, if possible, be folded around the edge of the cardboard head or form to prevent the strands from coming loose when the plastic copy is removed from the master.

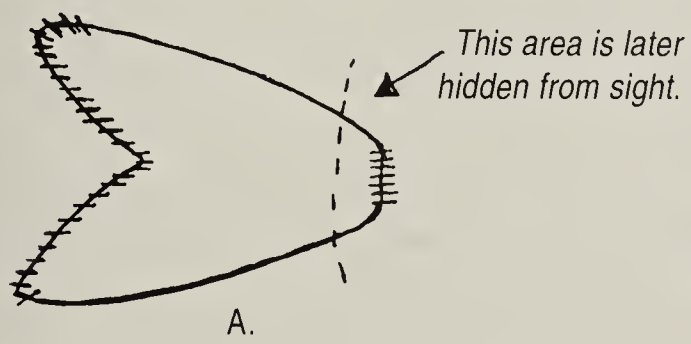
Examples of string fastened to background material. The dots indicate where the thread is fastened.

- It is often easier to sew thread into the display than to glue it onto the surface. Use as fine a needle as possible to avoid large holes.

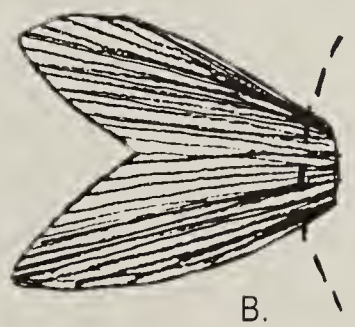


In this master for the cover of a book about shapes, the materials are cardboard and preglued string. The string is attached to the back side of the cover. It comes through a hole in the center of the spiral and continues past the man, ending once more on the back of the master, where it is firmly fastened. String or thread fastened in this manner is more apt to stay in place longer than if it is glued directly on the surface of the display.

- If you have a large area to cover with thread, like the fish's tail shown here, make tiny incisions in the edge of the cardboard form with a scalpel or razor blade (see A) and then wrap the thread around the form using one continuous strand (see B). It is not necessary to glue the thread to the surface of the cardboard form. Fasten the thread securely before and after winding it around the form.

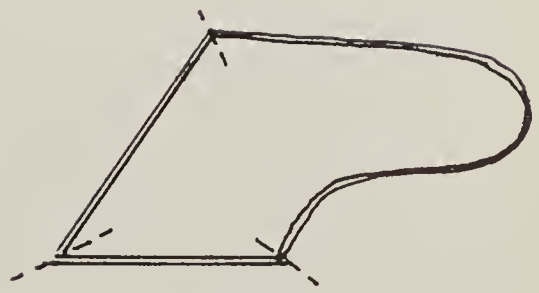


A.

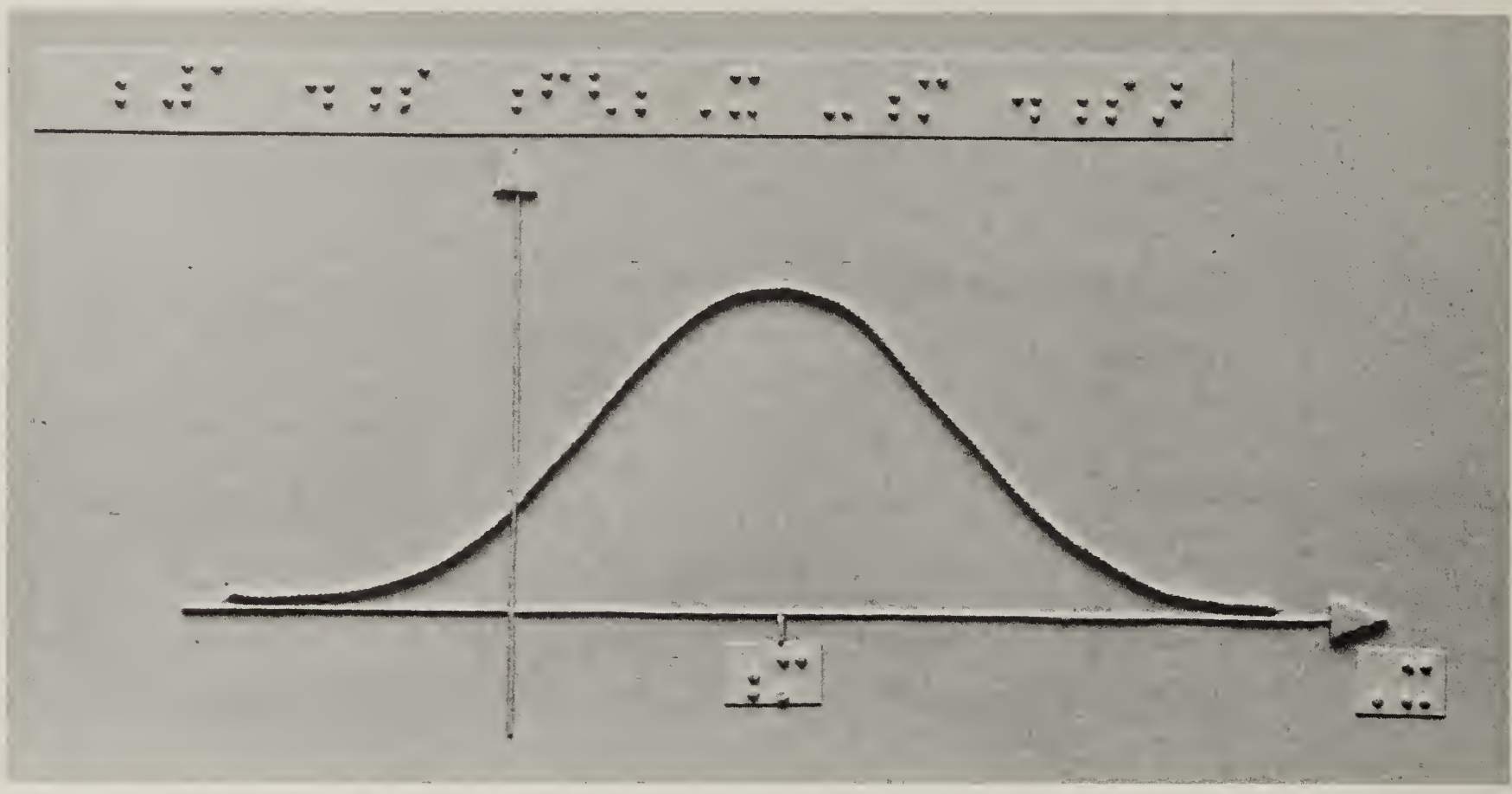


B.

- Most string or thread should be firmly fastened to its background. To prevent long lengths of string or thread from breaking away from the background when the plastic copy is removed from the master, cut the string into several lengths when forming outline figures. The cuts should be made at points where the lines form angles; cuts are not necessary along a curved line, because there is little tension along such a line. This technique will distribute the tension along the line, enable you to make sharper corners, and ensure a better point of adhesion at a sensitive spot. The edges or ends of the threads or strings should touch each other.



Cuts should be made in string at points where the lines form angles.

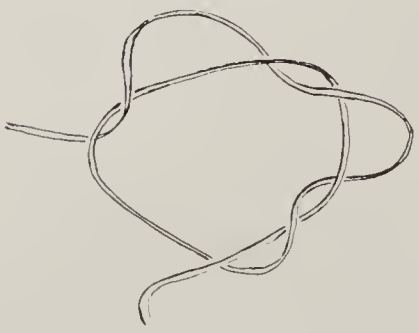


Two different grades of string in a diagram. Reader attention is focused on the heavier string.

After placing the string or thread on the background material, cut it to the desired length while the glue is still wet. This will allow you to scrape off any excess glue when the extra string or thread is removed. Use a scalpel or razor blade. The incisions should be so sharp and small that they will not be felt in the plastic copy.

- The string technique, combined with any raised, or embossing, technique, gives a wider variety of lines to a paper buildup. Lines made with an embossing tool (see section on "Embossed Paper Displays" in this chapter) could represent the form as a whole, whereas the string might represent those lines that should be emphasized to give the desired information (see above).

A. For a small knot.



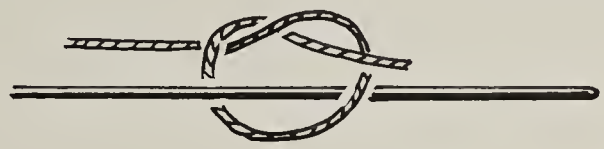
B. *For a bigger knot.*

Knotting

Knots may be added to vary the texture of string or thread. Fine thread should be preglued before knotting. String should not be preglued; it should be glued after the knot is formed. The pattern can be changed by increasing or decreasing the distance between knots or by varying either the size of the knots themselves or the weight of the thread. The size of the knot will increase as the number of loops increases (see A and B).

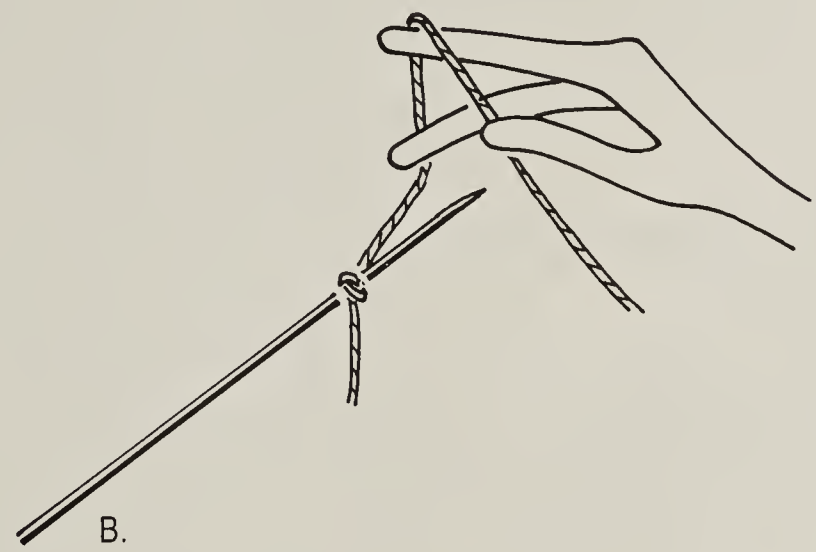
Use the following technique to create a series of knots on the same string:

1. Tie the end of the string to a short stick or a knitting needle that is pointed on both ends. If you are right-handed, hold the needle in your left hand. Hold the knot in place with your index finger.



2. Take the string in your right hand (see A), and spread out your index finger and second finger (see B).

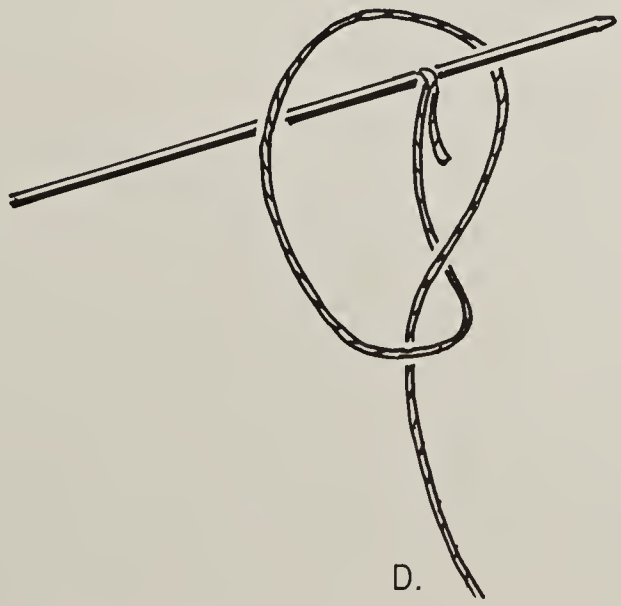
A.



B.

3. Stick the needle through the loop between your index finger and thumb (see C). Put the loop *over* the knot on the needle and pull the long end of the string to close the loop (see D). The loop should be able to glide along the needle.

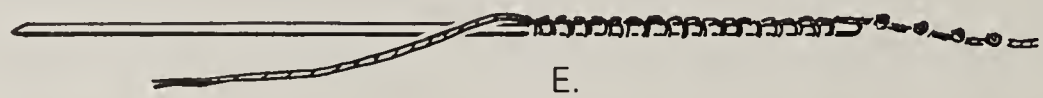
C.



D.

4. Repeat this process until there are as many loops on the needle as desired knots on the string (see E). Remove the string from the "original" knot end of the needle. As you pull the string off, the knots on the needle will form at equal intervals along the string.

   Note that the distance between the knots depends on the size of the string or thread and the size of the stick or needle that is used. Cut off as much knot string as needed, leaving the rest of the loops on the needle for future use.

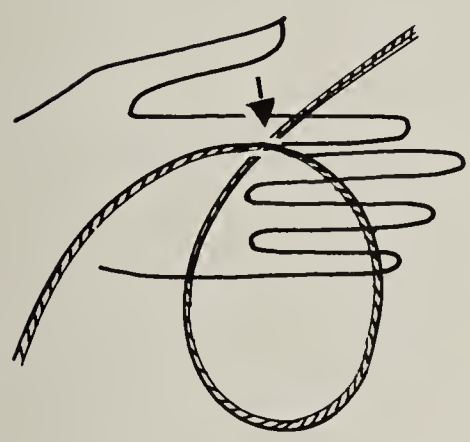


E.

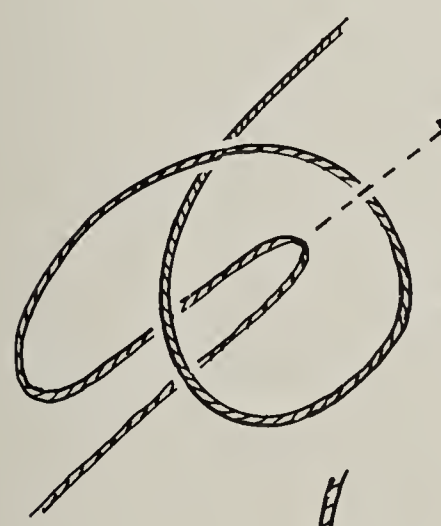
Map using knotted and unknotted string. Lines are of varying coarseness. The arrows are strings with knot heads.

Use the following technique to make a chain with string or thread:

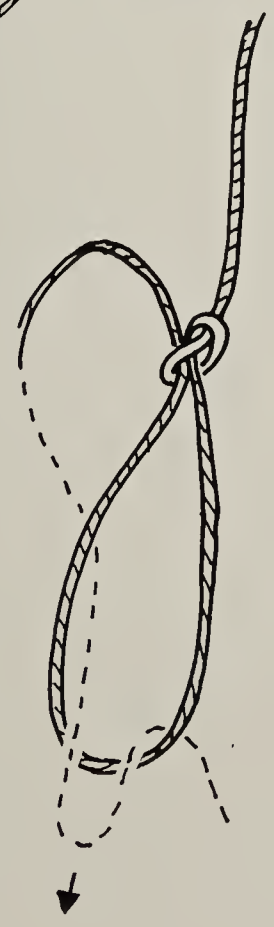
1. Take the string in your left hand between your thumb and fore-finger.



2. With your right hand, make a loop with the string.



3. Make a second loop and pull it through the first loop.



4. Keep pulling the new loop until the string forms a knot.

5. Repeat the procedure until the desired length of chain is reached, and then pull the string end all the way through the final loop. This will lock the chain and keep it from unraveling.

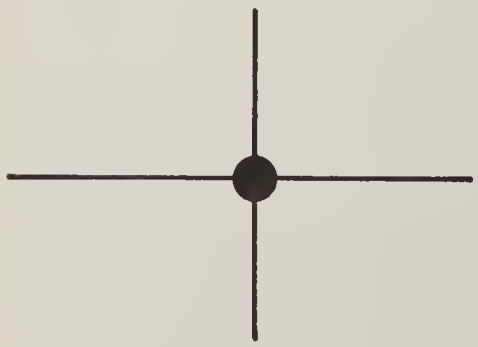
Note that to fasten the string or thread chain in place, you must sew the beginning of the chain through the background material, fastening it on the back. Glue the chain in place. To end the chain, pull the string or thread through the final loop—pull it tight. Make a small hole in the background material and pull the string or thread through to the back. Fasten the string or thread securely.

Additional Tips

The following are additional suggestions for the use of string or thread:

- A number of silk or cotton threads twisted into a string or twisted around a string will increase the variety and thickness of available lines. Be sure to stitch the threads firmly into the background material.
- A tuft or wisp of thick thread may represent the branching out of nerves or roots.
- A thin line of crochet work created by looping and intertwining thread with a hooked needle makes an interesting texture.
- A short string or thread with one knot at the end can represent an arrow in a display.
- Lines and dots are often used in graphs or diagrams. String or thread are excellent materials for lines. Dots can be made of paper, cardboard, leather, wood, fabric, metal, or cork. To combine lines and dots, as in a graph, the dots can be cut into the string (see A). The dots can also be mounted over the string, when two strings cross each other (see B).

A.



B.

Note that you should allow each dot to sit on a spot of glue until the glue is partially dry. Then press down the dot to remove any possible air underneath it. Do not allow the dot to hang freely on top of the thread. Fill in the empty area under the dot with glue to prevent it from being ripped off when the plastic copy is separated from the master in the event that you make copies later.

- String or thread can be used for a variety of purposes, for example, to make hair for people, manes and tails for animals, fine bones in skeletons, feathers on birds, directional arrows, fishtails, tree branches, roads, rain, routes, and textured areas.

Wood, Leather, Fur, and Rubber Bands

Wooden and leather (as opposed to vinyl, which might melt from the heat of a machine) components in a display can stand more of the wear and tear of copy making than can their paper equivalents. They will not split into layers, and their edges will not splay when the plastic copy is peeled from the master. Therefore, they are excellent for small islands in maps, hands with extended fingers, toes, tails, and all other thin protruding areas.

- Many different woods can be used. (Check lumberyards and hobby shops for suitable sizes and quality.) Balsa wood is easily formed with a hobby knife and sandpaper. Avoid undercutting and making holes into which the plastic could creep and fasten when the copies are removed from the master. Wood veneer is easily cut with a standard scissors or a scalpel; it does not readily split when cut across the grain. Wooden buttons of various sizes, with or without holes, are available in craft shops (see "Answer Cards and Pop Sheets" in this chapter).
- Sculpting in wood can also be copied in the vacuum-forming machine (see "The Vacuum-Forming Method" in this chapter), provided the maximum difference in height from the highest to the lowest point is not more than .19-.23 in. (5-6 mm). It may be necessary to bore air holes through the wood to allow the vacuum process to function.
- Leather is often available from old purses or gloves. Belts and straps can be made from used watch straps. Some bookbinders' leather has excellent grain for simulating the skin of elephants and other animals. The advantage of this leather is that it is exceptionally thin.
- Leather scraps, with or without fur, can be obtained from furriers. Some furs are usable in the vacuum-forming process. The hairs are clearly discernible in the plastic copy. Use real fur, not synthetic, when making a master that will be heated in the vacuum-forming machine.
- Leather, fiber, or rubber packing rings (washers) are useful for circling a letter or number to note its importance.
- Fiber circles and rings of various sizes are often available from local factories as a waste product. They can be used as point symbols on maps and diagrams.

- Rubber bands are useful as grids or axes on graphs or maps. Their advantage is that they can be moved perpendicularly or horizontally across the display, as desired, if the rubber band is large enough to slip over the complete display and the background material is firm enough to withstand its pressure. Rubber bands work well in a vacuum-forming machine. If the position of the rubber band is to be changed from display to display, while the same master is to be used (see "Answer Cards and Pop Sheets"), then it is not necessary to fasten or glue the band in place for the vacuum-forming process.

Clay

Clay can be used by sighted or blind persons to make a single display or to make a master from which many copies are reproduced. The components of this type of display are molded in self-drying clay or white modeling paste on a paper or cardboard backing. Clay often enables the master maker to produce more varied displays than those made by the paper-on-paper technique. There are a wide variety of textures, created by pressing various materials into the clay, that can only be made using this technique.

Several commercial clays are available. Your choice will be governed by the elasticity of the clay. It should not crack easily or shrink too much when drying, and it should adhere to the background surface when glued in place. The white modeling paste, Jarwi, from Belgium has proved most satisfactory for this use.

The following are suggestions that will be of help when working with clay:

- Do not make your displays too thick. The same principle applies to this type of technique as to all masters that are to be reproduced in plastic copies. For best results, the thickness should not exceed 3/16 in. (5 mm).
- There should be no undercut edges in the clay that will allow the heated plastic to creep between the forms and the background. Such edges make it impossible to remove the plastic from the master without destroying the original display.
- Choose the thickness of the background material with care.

The weight and fragility of the clay may make it necessary to use a firmer material than that used in a paper buildup. The more compact and thicker the material used, the greater the necessity for air holes in the background materials.

- The thinner parts of a clay form will dry more rapidly than the thicker areas. The difference in drying time may cause the form to bend and the edges to curl slightly instead of drying flat.
- Dry clay is brittle and will break easily. Broken parts can be welded together by dampening the areas to be joined and adding new or wet clay as an adhesive. If the break is clean, you may be able to secure the parts by gluing them onto the background with hobby glue.
- Cracks in the clay can be repaired by dampening the clay and pressing new clay into the broken area.
- If many plastic copies are to be made, it may be advantageous to shellac the clay forms to protect the surface from crumbling. Test the shellac before applying it to the display to be sure that it will not become sticky in the heat of the vacuum-forming machine and adhere to the plastic copy. Talcum powder, dusted lightly over the shellacked areas, may help to alleviate this problem.

Sand

Sand may be used for relief areas when commercial sandpaper is not available.

- Mix paint and sand together. The amount of sand determines the density of the texture. Paint the area directly on the display or on a separate form to be mounted on the display when dry.
- Avoid sprinkling sand over an area of wet glue, unless the display is to be mass-produced in plastic copies. Loose sand often sticks to the fingers of the reader and interferes with the examination of other textures or symbols on the display.

PAPER AND TAPE MAPS AND CHARTS

Maps and charts made from paper and tape range from simple mobility maps to complicated graphic diagrams. The

display is built up on a paper, cardboard, wooden, or metal background.

Different types and widths of tape can be used in the same diagram—extra-wide tape for streets and narrow tape for sidewalks or for bars on a chart. This is also a suitable system for low vision readers. Black tapes show up well against a white or yellow background, as do white tapes against a black background. Among the many types of tape are:

- paper or plastic packaging tape;
- strapping tape, reinforced with glass fibers or with threads;
- carpeting or seaming tape, somewhat thicker than standard tapes;
- electrical tape;
- paper masking tape;
- textile tape, in a wide variety of widths and textures;
- surgical tape;
- graph tape, which is obtainable in very narrow widths and can be formed into curves;
- self-adhesive plastic tapes, in a wide variety of widths and textures (plastic Scotch™ tape is available from the 3M Company; see "Sources of Materials and Equipment," Appendix 3 for address);
- magnetic tape;
- marking tape, for use in a labeling machine (brand name dymo, from Esselte Dymo International, with outlets in all European countries; see "Sources of Materials and Equipment," Appendix 3 for address);
- insulation tape;
- caulking tape;
- rubberized cork tape, for pipe insulation;
- PVC foam tape, in various thicknesses;
- aluminum-foil tape, used for insulation.

If you are planning to use your display as a master in a vacuum-forming machine (see "The Vacuum-Forming Method"), be sure to test the desired tapes in the heat before using them on your final display. Some narrow plastic graph tapes tend to swell a bit when heated, but they do not melt or fasten to the plastic copies when the master is removed. (Tape tested: self-adhesive plastic tape produced by Mecanorma, available in

widths of 1 in., 1/16 in., 1/32 in. (2.54 cm, .16 cm, .08 cm; see "Sources of Materials and Equipment," Appendix 3 for the address.)

Tape can also be used to add additional information to a plastic copy of a map or diagram already in use, such as in connecting points or parts not previously pointed out, explaining routes, or altering graphs. The advantage of tape is that it can be removed or placed in another position.

EMBOSSED PAPER DISPLAYS

Most beginners work with paper-on-paper displays first, because the technique is a relatively simple one. However, a relief display is made by embossing braille paper on the reverse side with various types of embossing tools. The desired display is drawn in reverse on the back side of the braille paper and will assume its proper direction and relief form when the paper is embossed and turned over. The maker of the display must, therefore, be mindful that he or she is working backwards.

This technique is suitable for one or more copies of simple pictures, maps, and graphs that do not require much detail or variety of line. The height of the relief is low and cannot be varied to any great degree. This type of display is not advisable for outdoor use unless a vacuum-formed plastic copy is made from the original master.

Embossing

The following is the procedure to create an embossed paper display:

1. The display may be sketched directly on the braille paper. Remember that if you emboss directly on this sketch, the final relief display will be in reverse when the page is turned over.
2. A printed graphic display may be transferred to the braille paper by placing a sheet of carbon paper under the braille paper. The carbon side should face the back side of the braille paper. Place your original sketch or printed material on top of the braille paper. Trace the lines of the graphic display. The lines will be transferred in a reverse image to the back side of the braille paper.

3. Place the braille paper, back side up, on a thin rubber drawing pad, a neoprene pad, a magazine, or any other surface that will allow an imprint when a semisharp instrument is drawn over the paper. The most common material is gum rubber of about .002 in. to .078 in. (.05 mm to 2 mm).
4. Retrace the drawing with an embossing tool. (Much of this information is also applicable to embossing in metal foil.)

If the display is to be used with a braille text of any length, it is advisable to braille the page in the desired areas first, before embossing the display on the opposite side. Inserting an embossed page in a braillewriter tends to flatten the embossed areas on the page. A slate and stylus can also be used to braille the necessary descriptions or labels after the drawing is completed, although this too may tend to flatten an embossed area if the embossing is done on a foil sheet.

A combination of embossing and string technique (see section on "String and Thread," this chapter) will increase the variety of lines in the diagram. It may be necessary to use this technique if it is difficult to emboss a smooth line on the braille paper. Braille papers manufactured in different countries have varying levels of density; therefore they react differently to the amount of pressure applied by the reader. Their ability to maintain a sharp imprint may differ.

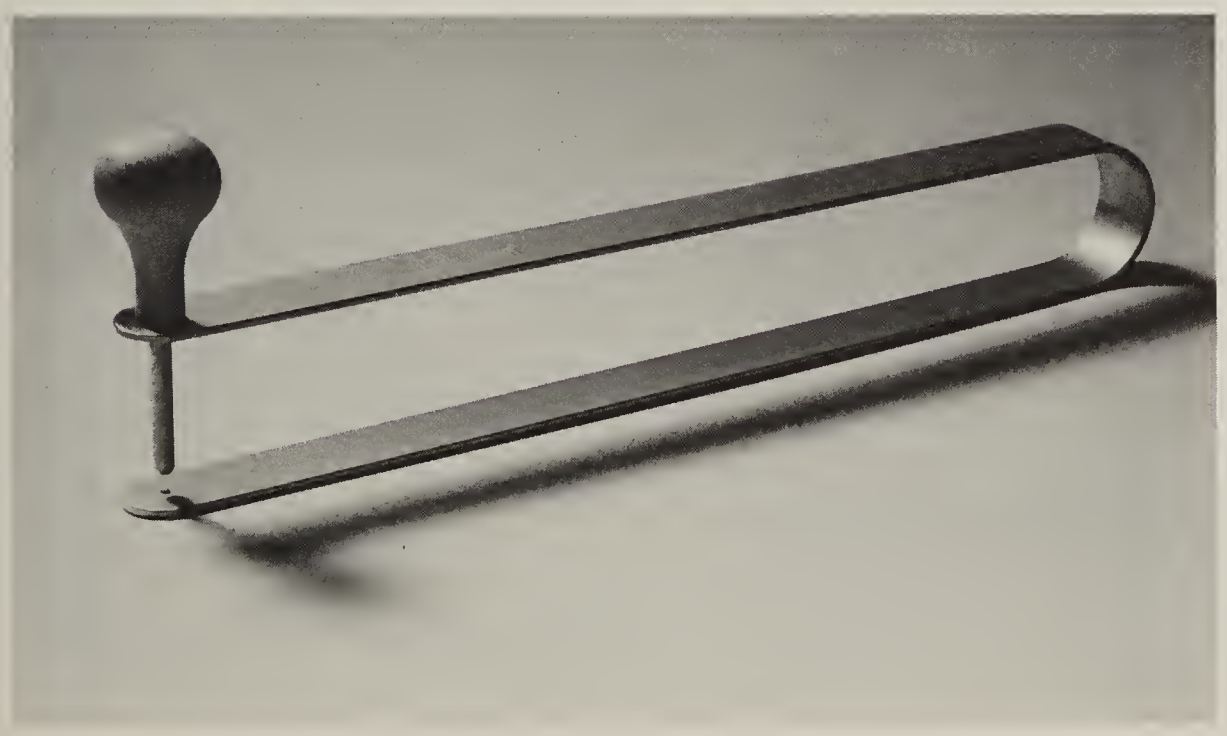
A contrasting texture of embossed lines, point symbols, and areal patterns is important for recognition and emphasis. The most important information should be represented by a rough sharp line contra a smooth line. (Information concerning the use of lines, points, and areal symbols is found in Chapter 6.)

Textured areas embossed on separate sheets of braille paper are useful in paper-on-paper displays. They can be cut to a desired size and shape and mounted on cardboard or directly glued onto a display which has several different elevations. However, when certain glues are used the braille paper tends to lose its character and become soft, and the embossed symbols or braille cells on the glued area are not satisfactory. If this is the case, use double-backed tape to attach the embossed area to its backing. Other glues are excellent. They fill up the cavities on the reverse side of the embossed symbol or area and prolong the life of the relief. Therefore, test the glue that you use before applying it to your final display.

Tools for Embossing

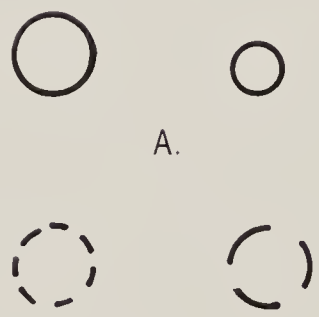
Embossing tools include:

- Ballpoint pens, which are inexpensive and make excellent tools, whether they have run dry or not. By holding a ballpoint pen perpendicular to the paper, you can make dots; by holding it in a normal writing position, you can make straight or curved lines.
- A spur or tracing wheel, which consists of a handle and a small wheel with points around its circumference. When the wheel is moved over the reverse side of the braille paper, a row of dots or dashes will be embossed on the opposite side of the paper. A variety of lines can be produced by using wheels that vary in size, shape of the spur, and distance between spurs. These tools are available from Howe Press and from the Royal National Institute for the Blind (RNIB) (see "Sources of Materials and Equipment," Appendix 3 for the addresses).
- A tracing wheel used to transfer sewing patterns to fabric will also work well as an embossing tool. Such a spur wheel can be purchased in any store that sells sewing materials.
- Braille tongs or freehand drawing stylus (also called a correction tong) is a tong-type instrument that presses up a single relief dot of standard braille size. The handle of the tongs is about 8.6 in. (22 cm) long, which allows one to reach all sections of an average sheet of braille paper. Tongs are available from Howe Press.
- Leather-working tools, knitting needles, and dental instruments are good embossing tools, as is metal tubing of



Freehand drawing stylus (tongs), used to make the relief picture shown on the following page of the man and the ostrich.

Relief picture done with tongs and spur wheel.



A.

B.

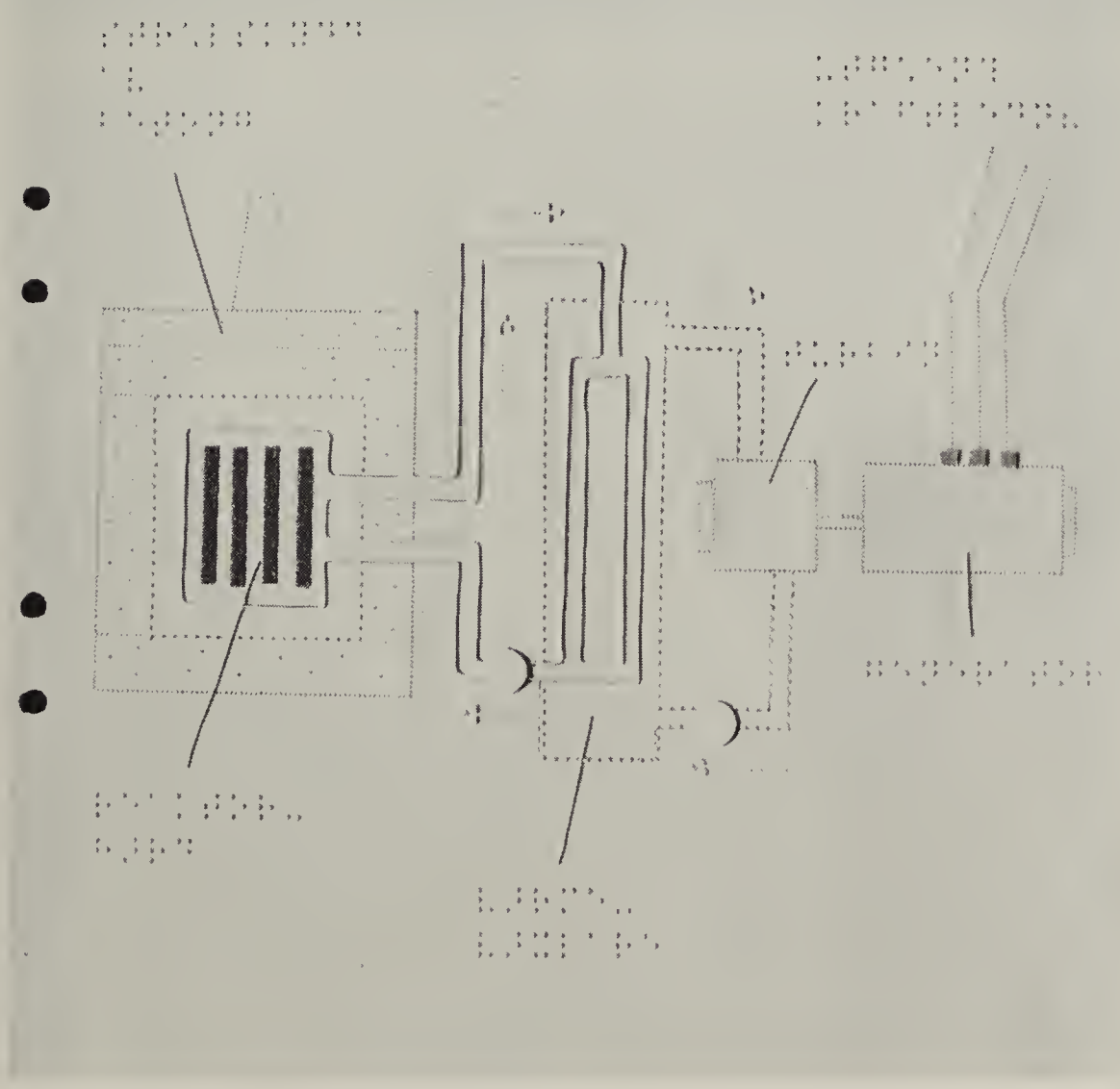
assorted dimensions—excellent for embossing hollow dots or rings (see A). To vary the embossed ring, file notches around the open edge of the tube at various intervals (see B).

Some of the variety of embossing tools is reflected in the range of spur wheels and other tools available. For example, an ordinary spur wheel is a serrated wheel revolving in a plated brass handle. It is used for making continuous embossed lines. A cantelo is a small spur wheel fitted to a square brass shank with a crosspiece at one end. This tool is recommended for

Embossing tools. They are from the Royal National Institute for the Blind.

drawing embossed diagrams, since the crosspiece helps to guide the wheel along a ruler. A castor is a spur wheel intended for drawing curves and circles. The lower section of the handle is swivelled to allow the wheel to be guided easily. An upward embossing spur wheel is designed to produce embossed lines upward. The hooked points of the wheel penetrate the paper and pull up the surface, leaving a distinct raised line, which can easily be defined without turning over the paper. Also useful is the multihead embossing tool, which has different embossing heads that screw into a metal handle.

The use of various embossing techniques helps the blind reader understand the illustration seen here of a section of a reactor. Spur wheels, correction tongs, coarse thread, sandpaper, and appliquéd cardboard make this possible. It is unfortunate, however, that the master maker thought it necessary to connect the different parts of the display to the braille labels with thread. The thread is too dominant to the touch, becomes part of the overall form, and distracts the blind reader.



The use of many embossing techniques helps make this display of a reactor understandable to blind readers.

Sewing-Machine Diagrams

Relief pictures and maps can be made on thick braille paper, foil, or cardboard by using a sewing machine, with or without thread or threads of varying thickness. The variety of stitches available on present-day machines makes this an interesting technique that can also be mass-produced though the vacuum-forming process.

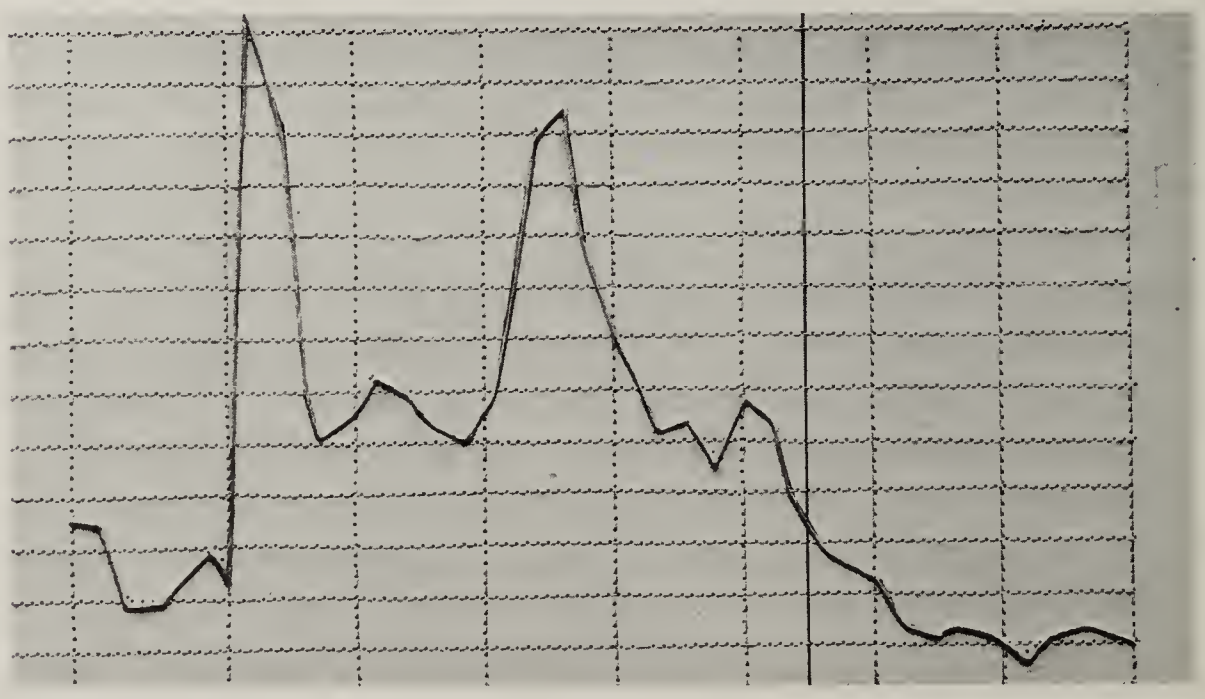
To use this technique:

1. Draw the pattern area on braille paper, thin cardboard, or foil.
2. Place the paper in the machine and sew directly onto the paper. Cardboard forms, point symbols, additional line and areal symbols, and sandpaper and such can be glued to the surface of the display if desired.

Note that with this technique, it is possible to augment the variety of textures and patterns available for other tactile graphic displays by using the following procedure:

- Make a large area of texture on paper, foil, or cardboard. A textured area may be a combination of several different stitches, provided the result is distinct to the touch and not a cluttered or confusing pattern.
- Cut out a desired area of texture with scalpel or scissors and glue it to the matrix.

The sewing-machine technique is excellent for making a discreet grid for a graph (see A). The line on the graph is made



A.

with string. This type of display can be copied in a vacuum-forming machine without losing the grid lines.

The needle of an old-fashioned sewing machine can be replaced by a tool that will make dots in a metal plate of the type used in the mass production of braille books—stereotype printing (see B). Simple pictures can be made directly on the metal plate. The metal to use is zinc that is approximately .08 in. (.2 mm) thick, and it can be metal waste from canning factories or sheet metal. The master for a book cover can be made using this machine (see C).

B.

C.

Stereotype printing produces a pressed-paper relief, not a relief made through the vacuum-forming process. Only one elevation can be obtained in the printed pictures, maps, or braille text produced.

This type of printing is done on folded metal sheets, by the method just described using a stereotyping machine, or by a large braille stamping machine. The embossed zinc plates are put onto a printing press with braille paper between the two

Correcting an error in a braille stereotype plate.

metal sheets, and braille is embossed onto the paper through pressure. This technique was prevalent before the introduction of electronic and computer equipment.

Embossed Aluminum-Foil Displays

Aluminum foil is easily embossed with solid or broken lines and a variety of textures. The display is drawn in reverse on the back of the foil. The foil is then placed, back side up, on a rubber pad, a raised-line drawing board, a magazine, or some other material that will have enough give to allow an imprint to be made in the metal. Lines, points, and textures are embossed into the foil in this position. When the foil is again turned over, the display will be in relief. Errors can be easily smoothed away and the area reembossed as desired.

A wide variety of tools can be used for embossing, including spur wheels, wooden sticks, cuticle sticks, ballpoint pens, tracing wheels, nails, leather-working tools, dental instruments, and drill bits (rolled sideways). You can also experiment with objects at hand, such as a fork or a comb.

Aluminum foil permits a greater variety in embossed

textures than does an embossed paper page, because of contrast in height. The stronger the pressure on the foil, the higher the symbol will be on the reversed side. The foil display can be a single picture or map or it can be used as a master for plastic copies produced in a vacuum-forming machine. Rolls of commercial foil, .005 in. (.127 mm) thick, are sprayed on one side with an off-white paint to facilitate drawing with a

Aluminum foil for making tangible diagrams.

pen, pencil, or stylus. The rolls are 11 in. (27.9 cm) wide and approximately 150 ft. (45 m) long. They are available from the American Printing House for the Blind (APH). Sheets of commercial aluminum foil .003 in. (.076 mm) thick are packed in boxes containing 2 pounds or approximately 54 sheets. Each sheet is 10 in. by 12 in. (25.4 cm by 30.5 cm). Boxes of sheets are available from RNIB. Aluminum foil sheets or rolls are also available at craft shops, from the American Foundation for the Blind (AFB), and from Howe Press. Embossing tools are also obtainable from these sources (see "Sources of Materials and Equipment," Appendix 3 for addresses).

Suggestions and Considerations

The following are some suggestions:

- If the relief in the plastic copy is not as sharp as the master, it may mean that the surface air cannot escape and a proper vacuum has not been formed. To eliminate this problem, perforate the foil with a fine needle, making tiny holes as close to the relief areas as possible.
- Metal foil can be attached to a background material, such as paper or cardboard. Spots of glue at various points on the foil will keep the metal in place and allow it to expand and contract without buckling when it is subjected to the heat of the vacuum-forming machine. Double-sided tape can also be used to affix the foil to other material.
- Braille text or labels in the display can be embossed with a slate and stylus. Large-size ink-type letters can also be embossed. It is advisable to use a slate and stylus before embossing lines, points, or textures into the foil. The leaves of the slate tend to flatten embossed areas when they are pressed together to make the braille characters.
- Sandpaper and other materials can be glued to the front surface of the foil to vary the texture.

The advantages of foil diagrams include:

- The metal foil becomes a permanent master than can be used many times.
- Both the height and texture of lines can be varied. Smooth lines as well as rough lines can be embossed directly into the metal foil.
- Large variations in texture can be obtained.
- Sharper edges for better legibility can be obtained, compared to the lines embossed in a single paper sheet (not to be confused with a paper buildup).
- Additions can be made or removed easily.
- Sections can be erased and repatterned.
- It takes less time to make an embossed metal foil diagram than a paper buildup diagram.
- Young and old, sighted and blind, can all emboss in metal foil.

The disadvantages include:

- Edges are not as sharp and clear as those cut with a scalpel in other types of masters.
- Lines must be reworked several times to gain variety in height.
- Differences in layers (height through thickness) are not obtainable unless added pieces are glued onto the original plate.
- There is a danger of flattening sections of the diagram as you work on other parts of the same diagram.
- The size of the diagram is limited to the sizes of metal-foil rolls or sheets that are available.

The Tactile Graphics Kit with Guidebook

The Tactile Graphics Kit with Guidebook is used basically to create a master by embossing heavy-gauge aluminum foil with point, linear, and areal symbols. Its purpose is to provide interested individuals with a means of constructing readable tactile graphics displays. The kit is a general-purpose aid, containing all of the essential components for constructing tactile graphics of all types—maps, graphs, diagrams, and

The Tactile Graphics Kit with Guidebook.

charts. To help the user take maximal advantage of the kit, the *Tactile Graphics Guidebook* is included. This guidebook contains information pertinent to the use of the kit's components, characteristics of the design of tactile displays, and suggestions for training blind persons in reading and in the interpretation of tactile displays.

The kit provides the means for producing seven kinds of lines, seven point symbols or shapes, and four areal patterns, including the specialized tools needed to produce these symbols and a number of accessory tools and materials for designing and embossing the master image. It is available from APH.

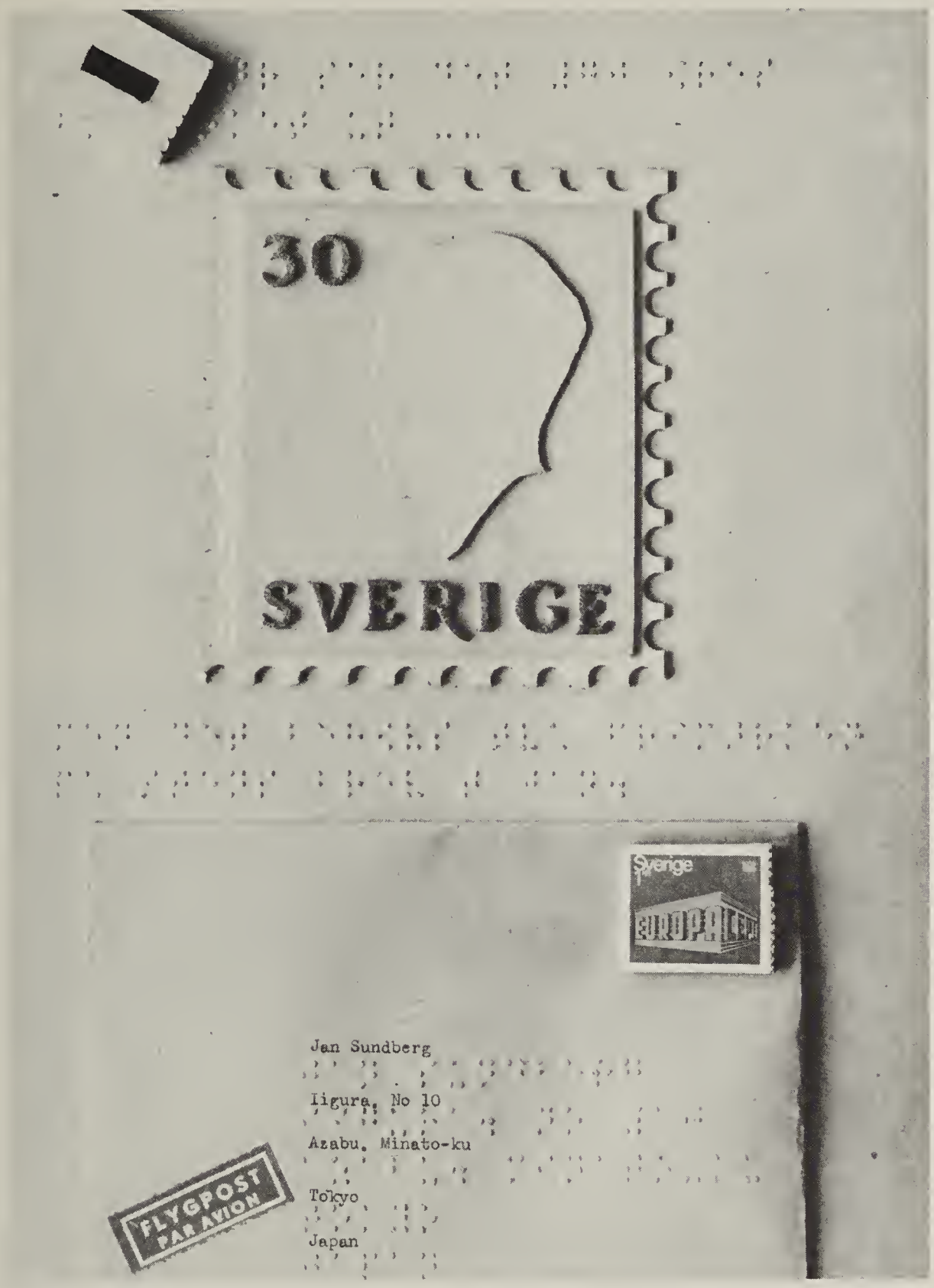
DISPLAYS WITH MOVABLE PARTS

A major example of a display with movable parts is the tactile-experience picture with a firefighter sliding down a firehouse pole or with car wheels that turn, doors that open and close, arms and legs that go up and down, purses that open, or zippers, snaps, and buttons that function. These are a few of the many possibilities. Magnets are useful in these displays. They can be used to fasten stamps on a letter or to move a figure, animal, or object within a picture or throughout a book.

Moving parts fascinate all children, both sighted and blind. Remember, however, that loose objects can easily get lost. A picture without all of its parts loses part of its purpose. A string attached to the loose object may help to solve this problem.

Movable parts can also be added to a mass-produced plastic copy. Two examples are a clock and a thermometer:

- To make a clock without hands, fasten movable hands to the clock's face with a pronged paper fastener.
- To make a thermometer without the thin column of mercury in the center of the tube, cut one or two slits into the tube of the thermometer. Strips of paper, sandpaper, or embossed plastic can be pulled up or down as they pass through the tube. Half of the surface of the strip should be covered with a textured area that is the substitute for the mercury in the tube.



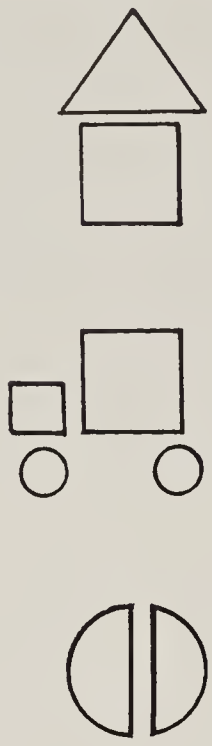
A page from the children's tactile-experience book *A Letter Means So Much* (Edman, 1970). A piece of metal in the upper right-hand corner of the envelope and a magnet cut into the cardboard backing of the stamp help children go through the motions of mailing a letter. Children quickly realize that the stamp will not "stick" anywhere else on the envelope—an important lesson to learn.

The Puzzle Technique

The puzzle technique is used to create a type of display with movable parts that is designed with separate forms that fit into indented areas on a page. On one side of the plastic copy, the area is raised. On the opposite side of the page, the raised area becomes an indented area.

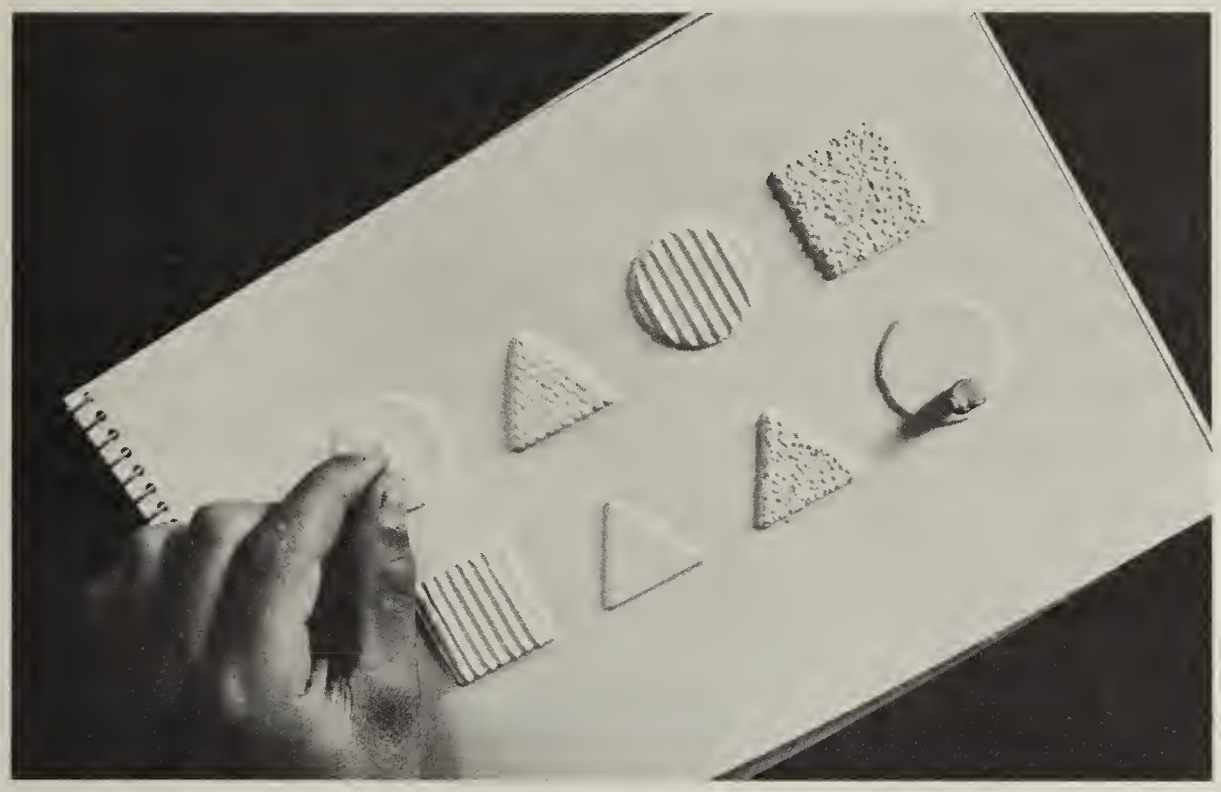
One side of the page can be used for word perception and for building up a vocabulary through the interpretation of picture forms and conversation about the placement, size,

Geometric cardboard shapes put together by children to form new shapes.



and shape of the various forms in the different displays. The reverse side of the page is a puzzle area, where the child can fit cardboard shapes of different sizes into their corresponding indentations. These shapes are included as part of the display package. *Learning through Feeling* (Edman & Svedberg, 1977), a series of eight books developed to train the tactile perception of visually impaired children, was made along these lines. The titles of the individual books in the series are self-explanatory: *Mark the Spot; Big and Small; Alike and Unlike; Long and Short; High and Low; Over and Under; Shape, Size and Texture;* and *A Mixture of Exercises.* The children using these books soon discovered that they could use several geometric cardboard shapes together to make a new form that is independent of their book layout—an unexpected development of this material.

This student is using the book *Over and Under* from the *Learning through Feeling* series (Edman & Svedberg, 1977). The book trains the child in the placement of the forms—right, left, over, under, in the middle, and so on—and leads the way to familiarity with buildup of dots in the braille cell.



Marking the location of two similar forms. This is a page from *Alike and Unlike*, one of the eight books in the *Learning through Feeling* series.

The back of a relief page makes the perfect puzzle area, provided that you have cardboard forms or three-dimensional objects that fit into the depressions. This page is from *Big and Small*, one of the eight books in the *Learning through Feeling* series. The cardboard forms are included in the series.

Flannel-Board Diagrams

Flannel-board diagrams are made up of movable items mounted on a flannel-covered board. The movable parts should be cut from lightweight material such as cardboard, sandpaper, or tapestry canvas. The back of these forms is covered with a cloth material that will adhere to the flannel but will not stick to it permanently.

Figures, animals, furniture, or other objects, cut out of cardboard and covered with realistic-feeling material, can easily be moved within the area to illustrate a story or size

relationship, for example. Strips of cardboard, sandpaper, or plastic can be quickly shifted within the area to explain the different crossings and routes of a mobility map. Small model cars and dolls can add to the informational value of this type of layout.

Magnetic-Board Diagrams

The purpose of magnetic-board diagrams is the same as that of flannel-board diagrams: to move items easily from one place to another in order to allow blind children or adults to place or move the components by themselves so that they can tell a story or give or receive information. This type of display is an effective mobility aid for teaching basic concepts such as the layouts of streets.

The necessary items are a metal background, which could be a refrigerator, a metal cabinet door (inexpensive backgrounds available in the home), or a tin sheet with a hardboard backing to make it rigid, and strips of magnetic tape or magnetic rubber 4.75 in. (about 12 cm). The tin and magnetic materials are available at hardware and office-supply stores; magnetic stripping is also available from RPH-SYN in Sweden. The tape can be fastened to the back of cardboard shapes to denote traffic lights, buildings, cars, trees, and the like.

Self-Adhesive Instant Display System

An enlarged picture of self-binding material, showing hooked nylon material on the left and rough nylon surface on the right. When the two surfaces are pressed together, they stick to each other in a temporary bond. They can subsequently be separated easily.

The principle of the self-adhesive instant display system is the same as that of the flannel-board system. The self-adhesive system is based on the use of Velcro or similar material. Velcro is the trademark for a product that consists of two types of nylon, one with tiny hooked threads, the other with a coarse surface. When they are pressed together, these two materials stick together in a bond that is strong but temporary; the materials can easily be separated again. Cardburr is the trade name for this type of product often found in department stores in Europe.

In displays using self-adhesive products, the material with the coarse surface, which can be purchased by the foot or centimeter, is mounted on a board, wall, or table. The hooked material, often sold in self-adhesive strips, is fastened to the back side of various three-dimensional objects or flat shapes.

These items can then be pressed onto the background in any desired position.

The Chang Tactual Diagram Kit, available from APH, is based on the Cardburr system. It consists of a folding baseboard covered with Velcro (18 in. by 12 in. (45.7 cm by 30.4 cm) unfolded), 2 stick figures, several angle segments, and 104 flat geometric forms made of fiberboard covered on the back with self-adhesive Cardburr tape.

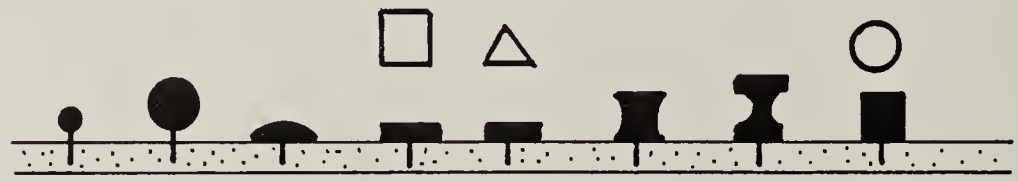
The Chang Tactual Diagram Kit.

Cork Maps and Graphs

Cork is easy to work with and simple to cut with a hobby knife or scissors. Sandpaper and cardboard forms can be glued onto the cork surface. Pins of all types, as well as separate shapes equipped with pins, can be readily moved about a cork background. Cork can be reused again and again without showing the pin holes. It is available in a variety of thicknesses. For a single display that will not be mass-produced, use a fairly thick cork that will allow you to use map pins.

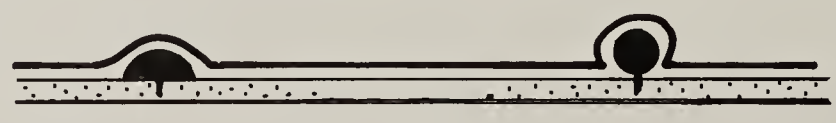
When using cork for individual shapes, it is advisable to paint all surfaces of the forms with a solution of glue and water. The thin mixture will penetrate the cork, giving it a longer life and preventing the edges from crumbling. It may be necessary to paint the cork several times before the material is firm.

A map pin can be almost any form that has a pin attached to it. Office-supply stores have a wide variety from which to choose. Many different sizes and shapes are used by companies to illustrate their organization in planning charts (see A). Stretching rubber bands, string, or thread from one pin to another is an excellent way to explain a route between cities on a map, make a curve in a diagram, or present a geometric problem.



A.

- For country maps, cut out the map in a simplified form so that the user can easily add or remove pins or forms from the map. The map can be mounted on tapestry canvas or cardboard if a background is necessary to hold it together or if several countries, states, or islands are involved. Otherwise, a simplified country, cut from thick cork and unmounted, allows the user to get the feel of the country in an entirely different way.
- For graphs and figures, select a fairly large piece or glue several pieces together onto a background. In this way, you are not limited to one type of graph, chart, or geometric figure.
- For mass-produced displays, choose a thin cork sheet from which to cut the forms. The advantage of cork is that the information on an original map or graph master can be changed from one copy to the next if you are using pins or tacks that fasten to the cork. Be sure that there is no area into which the plastic can creep under or around the pins or tacks (see B). (Rubber bands can withstand the heat of the vacuum-forming process. Be sure that the bands are rubber, not plastic.)



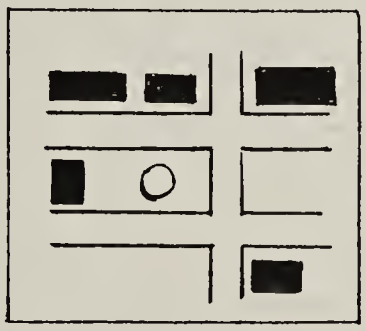
B.

THE VACUUM-FORMING METHOD

The vacuum-forming method is used when more than one copy of a relief display is needed. The copies produced are plastic relief copies, and the method is therefore particularly appropriate for making copies when durability of the display is important. Vacuum forming is probably the most widely used method for making plastic copies from a relief master. The widespread use of vacuum-forming machines has given rise to the term "thermoforming," referring to all reproduction of plastic copies from a relief master, irrespective of the type of manufacture of the machine involved.

At present, the plastic copies made by the vacuum-forming process cannot be reused as masters from which more copies can be made. When you undertake the process, it is essential that the room in which you do the vacuum forming should be well ventilated, since fumes are given off while plastic sheets are being heated.

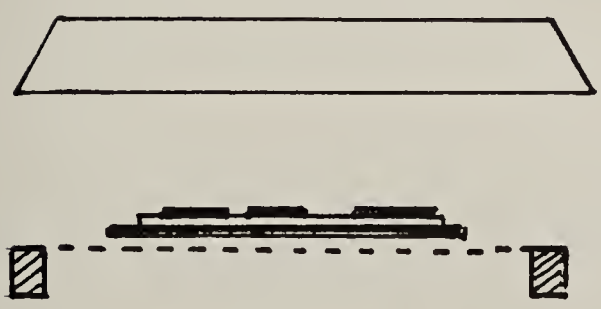
The following are the steps in the vacuum-forming method:



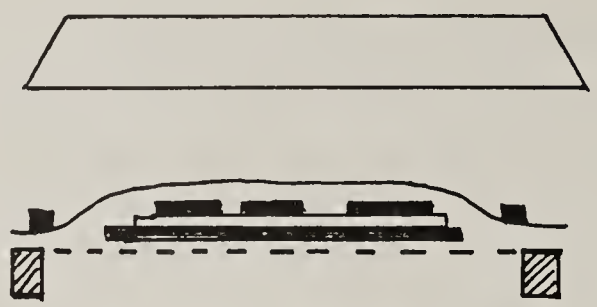
Top view.

Side view.

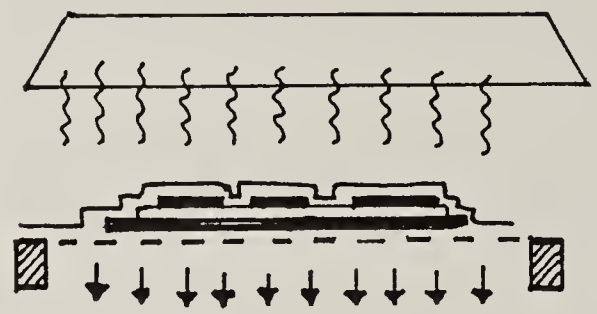
1. A master is made. A variety of masters can be used in a vacuum-forming machine. The background material should be stable enough to allow forms to be glued to it and still not lose its shape.



2. A master is placed on a perforated metal or fiberboard base in a vacuum-forming machine.



3. A sheet of plastic is placed over the master. The sheet is fastened in place with a frame that makes the four sides of the sheet air-tight.



4. A heating unit, at 392°-572° F (200°-300°C), is pulled over the plastic sheet, which is heated for approximately six seconds. The length of time depends on the thickness of the plastic used. Air is sucked out from below, through the holes in the base plate, forming a vacuum that forces the plastic sheet to be molded to the relief of the master.

Plastic copy.

5. The plastic copy is then peeled from the master. Some machines need approximately five seconds for cooling before removal of the plastic from the master.

Paper and foil displays can be vacuum formed, provided no forms are undercut or can be melted at a low temperature.

The process of vacuum forming is capable of elevations as high as 1/2 in. (13 mm). Although higher elevations can be obtained, it is not advisable to go beyond this height for material that will be used in braille books.

A plastic copy, made from the built-up master on the left, comes directly from the vacuum-forming machine.

Production Problems

Indistinct, unsharp plastic copies can be caused by several factors.

- The vacuum-forming machine was too hot.
- Material in the master was too dense or too thick (make the necessary air holes; see "Paper-on-Paper Buildup Displays," this chapter).
- The material received too short a "baking" time in the vacuum-forming machine.
- The plastic copy was separated from the master too quickly after it was formed.
- The materials used in the master required different "baking" times in the vacuum-forming machine. (A large area of metal may not work well with other materials. The metal may become too hot, causing the plastic to burn or to stick to the master.)

If the copy has a tendency to stick to the master, spray it with a little cold water as soon as it is removed from the machine. This will quickly reduce the heat, so that the copy can be easily peeled from the master. A water-spray bottle, like the kind used to spray plants, provides an ample spray.

To prevent the plastic from sticking to a very sensitive

surface—small items, thin threads, tight areas—dust the surface with talcum powder or spray it lightly with silicon before putting the master through the vacuum-forming process. Be careful not to get too much talcum powder on the master. It could fill up the corners and holes and cause a printed result that is not as sharp as expected.

If the cardboard used in the master has a tendency to split, splay, or peel off in sections, shellac the sensitive edges or areas. Test the shellac that is to be used to be sure that it does not become an adhesive agent in the heat of the machine (see "Paper-on-Paper Buildup Displays," this chapter).

To repair a master that has been gouged, scratched, or changed, remove or replace the unwanted information, and paint over the damaged area with shellac. Sand the area with the finest-grain sandpaper. Shellac the area again, and then sand it once more. Repeat this process until the surface is built up to the desired height and smoothness. It is often advisable to dust talcum powder over the area before making a new plastic copy.

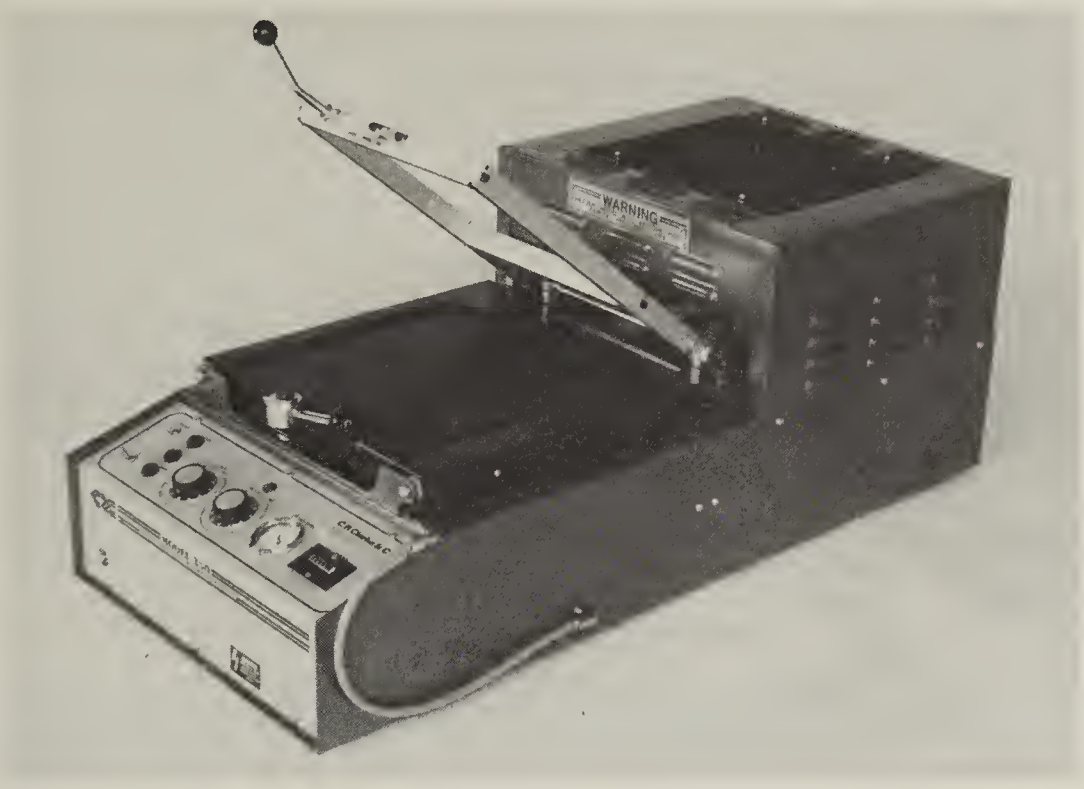
As Jansson (1984, p. 5) has noted:

> A special problem in connection with the use of plastic copies should also be mentioned. It is well known that copies made by the thermoform process may be much less readable than originals consisting of different materials, such as cloth, wallpaper, and sandpaper. This may depend upon a high sensibility of touch for the microstructure of a surface which is basic for perceiving what material the surface consists of. The microstructure of the original surfaces is at least partially lost in the copying process, and the microstructure of the plastic sheet dominates the perception.

Vacuum-Forming Machines

There are several different types of vacuum-forming machines. The one shown here is the Clarke Model 350, a low-profile vacuum-forming machine that was designed for the reproduction of braille and tactile diagrams. The standard platens and clamp frame supplied with each machine will accommodate the most commonly used sizes of sheets—11 in. by 11.5 in. (27.9 cm by 29.2 cm) and 11 in. by 8.5 in. (27.9 cm by 21.6 cm). Other sizes can be supplied to special order on request.

Reproduction is rapid with this machine. The maximum



The Clarke Model 350.

heating-cycle time is 18 seconds but typically is 2 seconds using PVC film of .004 in. (.10 mm) thickness. An adjustable timer, which is incorporated, automatically energizes the vacuum pump and provides an audible indication of when to withdraw the platen from the heater. The machine is also equipped with a resettable copy counter. The electrical specifications are 240 V-50 Hz or 120 V-60 Hz. For further information, write C.R. Clarke and Company (see "Sources of Materials and Equipment," Appendix 3 for address).

The E-Z Form is a simple, safe, and rapid machine for producing low-profile tactile graphics. Its maximum forming

The E-Z Form.

area is one inch less than each dimension of the sheet size. The sheet sizes are the same as the frame and platen sizes: 11 in. by 11.5 in. (27.9 cm by 29.2 cm), 9.76 in. by 11.5 in. (24.8 cm by 29.2 cm), 8.5 in. by 11 in. (21.6 cm by 27.9 cm), and 8.36 in. by 11.7 in. (27 cm by 35 cm).

The Maxi-Form can accommodate plastic relief displays of a larger size, such as mobility and general reference maps and large-scale diagrams. Its maximum forming area is 12.25 in. by 17.25 in. (31.1 cm by 43.8 cm). The size of the sheets is the same as the frame and platen sizes: 13.75 in. by 18.75 in. (34.9 cm by 47.6 cm).

The Creative-Form.

The Creative-Form is designed to reproduce high-profile teaching aids and relief maps. Objects and maps up to 1.25 in. (3.2 cm) high, 11 in. (27.9 cm) wide, and 17 in. (43.2 cm) long can be formed easily and rapidly. Its maximum forming area is 10.5 in. by 16.75 in. (26.7 cm by 42.5 cm). The sheet size is 13.75 in. by 18.75 in. (34.9 cm by 47.6 cm).

The E-Z Form, Maxi-Form, and Creative-Form are thermoform brailon duplicators available from the American Thermoform Corporation. Deutsche Blindenstudienanstalt and RNIB (see Appendix 3 for addresses) are other suppliers.

Choice of Plastics

The choice of plastics to be used in the vacuum-forming method depends on the use of the display. Following is a list of the types of plastics to use for various purposes:

- For most relief pictures, graphs, and maps, a thin plastic .006 in. to .10 in. (.15 mm to 2.54 mm) is recommended for maximum sharpness of the copy. This plastic is usually cream-colored or white.
- For embossed book covers, mobility maps that are not to be used in the field, calendars, sheets of standard geometric figures, and the like, a thicker plastic .012 in. (.3 mm) may be needed. Details may not be as sharp in this plastic as those embossed in a thinner plastic. However, this plastic is durable and comes in a wide variety of colors, both desirable qualities for material to be used with low vision students.
- For map or picture layovers for blind people or for low vision readers in which a clear relief map or picture layover is used on top of ink-printed material, the best choice is a clear plastic, .005 in. to .010 in. (.127 mm to .25 mm).
- For mobility maps to be used in the field, choose a pliable .010 in. (.25 mm) plastic that can withstand weather and that can be folded and refolded many times.

The plastics listed in Table 1 on the next page have been well tested. There may be many more on the market today that are equally as good or better.

Recycling and Cleaning Plastic Copies

Recycling takes advantage of materials that would otherwise be thrown away. The standard-size plastic relief material, about 11 in. by 11 1/2 in. (279 mm by 292 mm) can be replasted over a smaller master. The results are usually good. It may be necessary to make an additional frame for the vacuum-forming machine to accommodate the smaller plastic sheet. The used plastic will not be large enough for the standard frame because its edges have probably been trimmed away and there are holes from the former binding.

Soap and water are usually sufficient to clean plastic copies. If the plastic is sticky after tape or labels have been

TABLE 1. Types of Plastic, by Trade Name, Color, and Supplier

Type of Plastic	Trade Name	Color	Supplier[a]
.004 in. (.10 mm)			
Calandered vinyl	Brailon	cream	American Thermoform Corporation
Calandered vinyl	Brailon	cream	Royal National Institute for the Blind
Polyvinyl chloride foil	Flovic	white	Royal National Institute for the Blind
Polyvinyl chloride foil	H-5001	white/colored	Renolit Norge A:S:
.005 in. (.127 mm)			
Polythene		clear	Transatlantic Plastics
Polythene		clear	Turner Whitehead Industries
.006 in. (.15 mm)			
Polystyrene	Senosan H20	white	Senoplast Klepsch and Company
Polyvinyl chloride foil	H-5002	white	Renolit Norge A:S:
Polyvinyl chloride foil	H-5002	colored	Renolit Norge A:S:
Polyvinyl chloride foil	H-5002	clear	Renolit Norge A:S:
.008 in. (.20 mm)			
Calandered vinyl	Brailon	cream	American Thermoform Corporation
Calandered vinyl	Brailon	cream	Royal National Institute for the Blind
Polyvinyl chloride foil	H-5002	white	Renolit Norge A:S:
Polyvinyl chloride foil	H-6079	clear	Renolit Norge A:S:
.010 in. (.25 mm)			
Polystyrene	Bextrene	white	Graphic and Display Products
Polystyrene		white	Smith Brothers Asbestos
Polythene		clear	Transatlantic Plastics
Polythene		clear	Turner Whitehead Industries
Polyvinyl chloride foil	H-6079	clear	Renolit Norge A:S:
.012 in. (.30 mm)			
Polyvinyl chloride foil	H-5002	white/colored	Renolit Norge A:S:
Polyvinyl chloride foil	H-6079	clear	Renolit Norge A:S:

SOURCE: G.A. James and J.D. Armstrong, *Handbook on Mobility Maps* (Nottingham, England: University of Nottingham, Blind Mobility Research Unit, 1976).

[a]Addresses of suppliers are listed in Appendix 3.

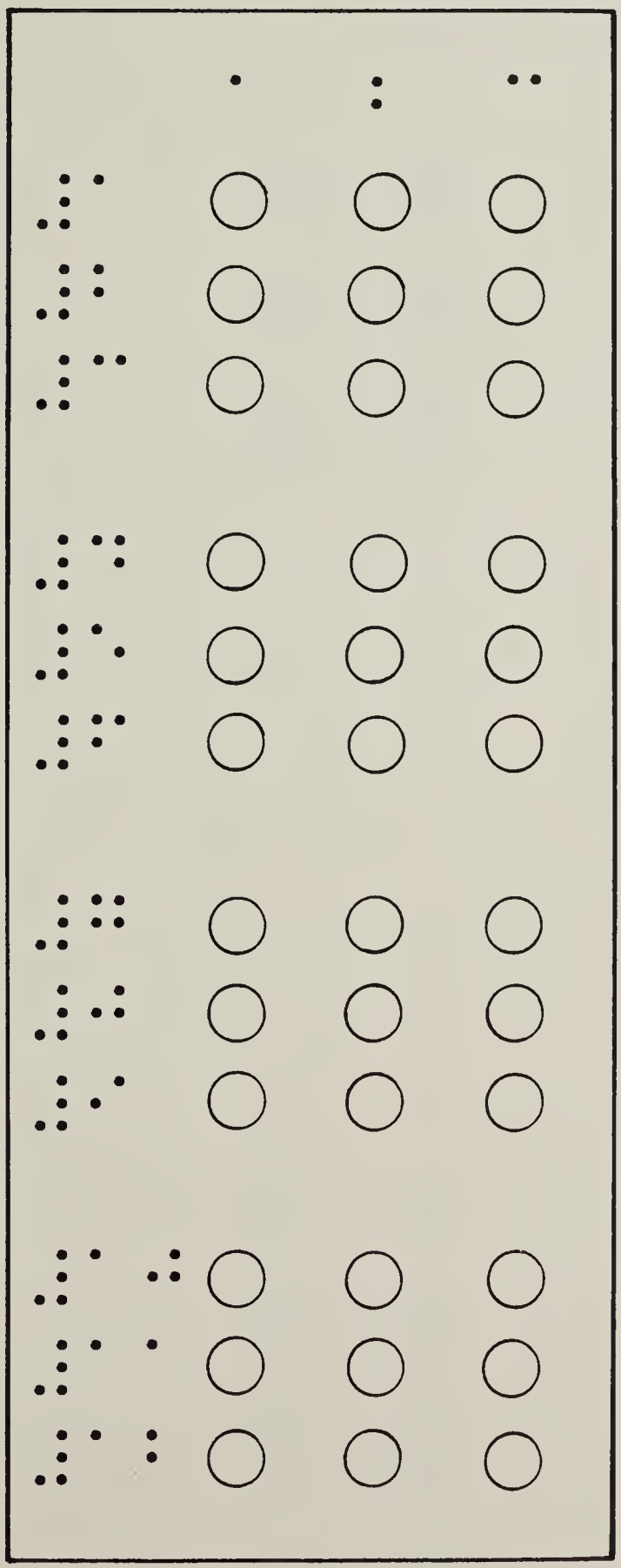
removed, wipe the area with paper toweling or cotton dipped in cleaning fluid, but do not use thinners or solvents such as turpentine. Test the cleaning liquid that you intend to use on a scrap of similar plastic before using it on the actual map or picture. If the liquid is not chemically suitable, it may make the plastic soft or sticky or cause it to lose its shape.

A special note: It may be difficult to read pictures, maps, and braille texts in warm climates or under other conditions that make hands and fingers sweat. Plastic becomes slippery with perspiration, which may make it difficult to understand the

relief displays. Dipping fingertips in talcum powder will ease this problem. Soap and water will clean the talcum powder off the plastic.

ANSWER CARDS AND POP SHEETS

Answer cards are a quick and easy solution to multiple-choice questions; they are a type of reader-participation display. The student uses the plastic copy to answer multiple-choice questions by pressing down dot A, B, or C. The dots remain down



brass paper fastener

upholstery nail

Answer card using upholstery nails (*actual size*).

until they are pushed up from the back of the card. The answer card can be used quite a few times, depending on the quality of the plastic copy.

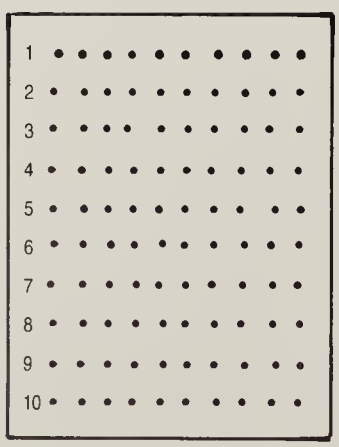
The master consists of a small board made of wood or cardboard that is fitted with rows of upholstery nails or brass paper fasteners (see A and B). It is important that the heads of the nails or fasteners be well rounded. If they are flatter, the person using the answer cards will have a hard time pressing down the dot in the plastic copy and may also have difficulty keeping the dot pressed down.

The card shown on page 77 in its actual size is a workable size. There are three rows of nails across the card and six to thirteen rows vertically. The number of rows is determined by the card's use and can therefore vary. Each row is numbered in braille to facilitate checking the answer to a particular question. An enlarged version of this system can also be applied to mathematics for beginners. Children who have used this system call the cards pop sheets.

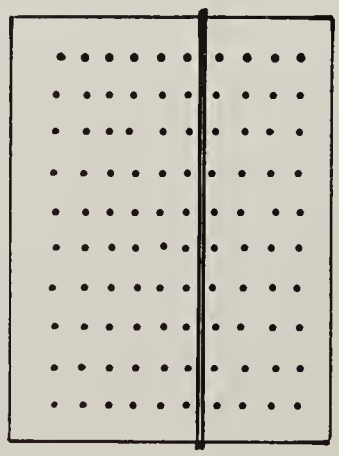
Note that four answer cards of the actual size that was shown can be made on the same master. The plastic copies are then cut apart to form a single card. This system saves time and does not waste plastic that would otherwise be cut away from one single card.

Pop sheets for mathematics are used by students who are studying elementary mathematics (addition, subtraction, and multiplication). The press-down technique for working out mathematical problems is similar to that of answer cards. The system is discussed in Chapter 8.

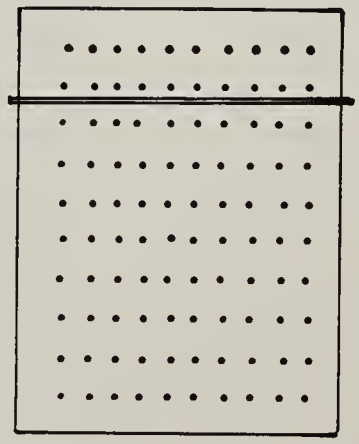
A pop sheet is constructed with ten rows of ten embossed dots placed vertically across a standard page, 8.27 in. by 11.69 in. (A4, which is 21 cm by 29.7 cm). (Note that the A4 standard



A.



B.



C.

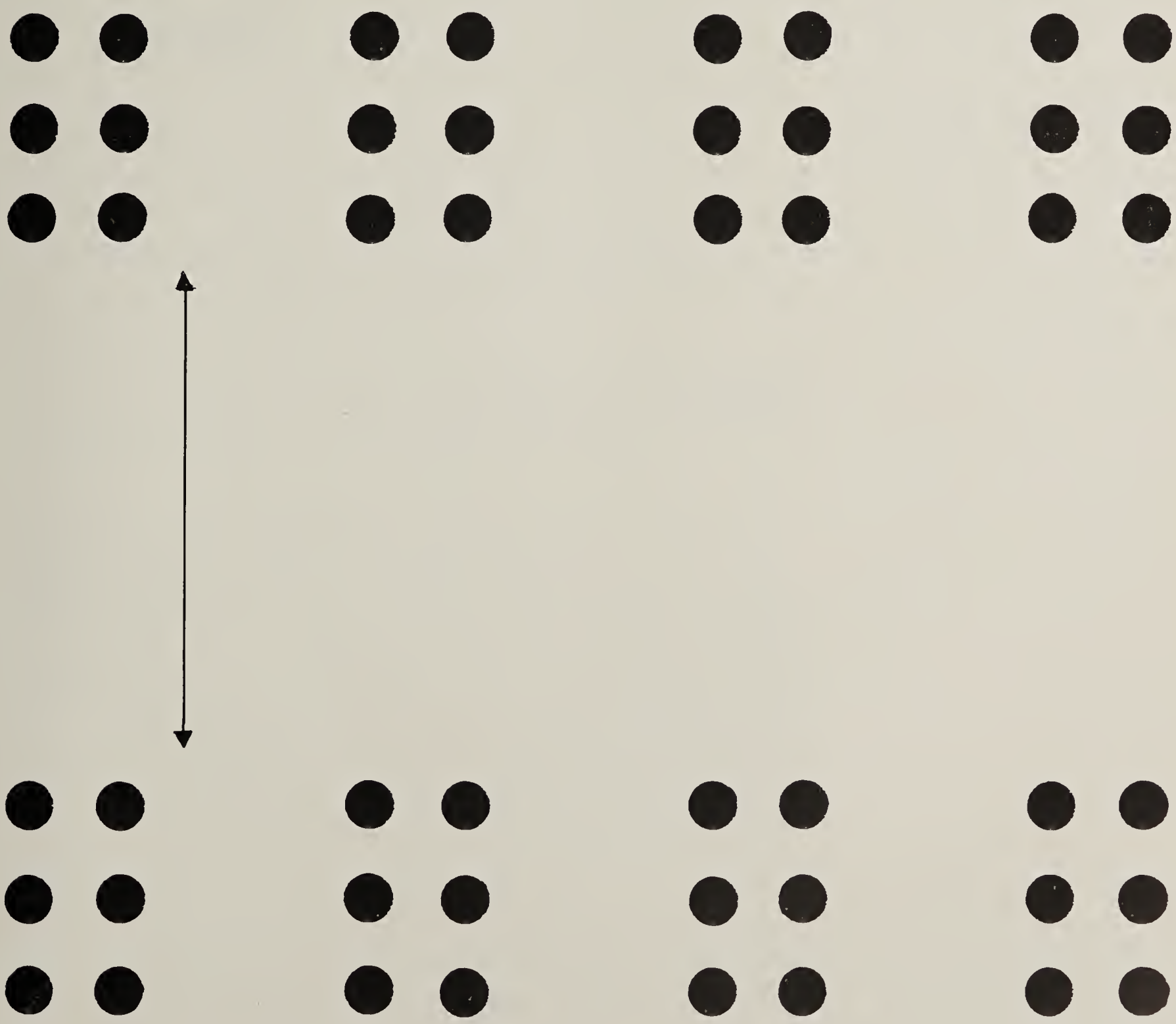
page is the standard European size; in other places, the standard may be based on a different size.) Each row of dots is preceded by a number on the left-hand side (see A).

Particular groups of dots can be isolated by stretching a rubber band horizontally or vertically over the master before vacuum forming the sheet. The removable rubber band allows the master to be used in a variety of dot combinations (see B and C). A rubber band withstands the heat of the vacuum-forming process very well; do not use plastic bands.

Embossed dots for very young users can be made from wooden forms glued onto a cardboard backing. These dots are large and easily depressed.

Large embossed dot made for very young readers.

This example of dot placement shows both actual size and placement for pop sheets for braille cells.



Embossed dots for older students are made from brass paper fasteners mounted into a cardboard backing or upholstery nails of a similar size fastened to a wooden backing. (The actual size is shown in the answer card illustrated earlier in this section.) Upholstery nails seem to depress more easily than paper fasteners.

Pop sheets for braille cells are used by beginning readers. They are constructed in the same way as the mathematical pop sheets. The only difference is in the placement of the dots to form individual braille cells, with a standard amount of spacing between each cell, as shown in the illustration of dot placement on the previous page. A horizontal display of four rows, nine braille cells in each row, is more advantageous than a vertical display of five rows, six braille cells in each row. The length of the individual words can be longer in the horizontal version.

The example of dot placement on page 79 shows actual size and placement. The large distance between the rows of braille cells marks a definite division of rows and seems necessary for persons who are learning braille. However, this distance can be changed to suit a particular student.

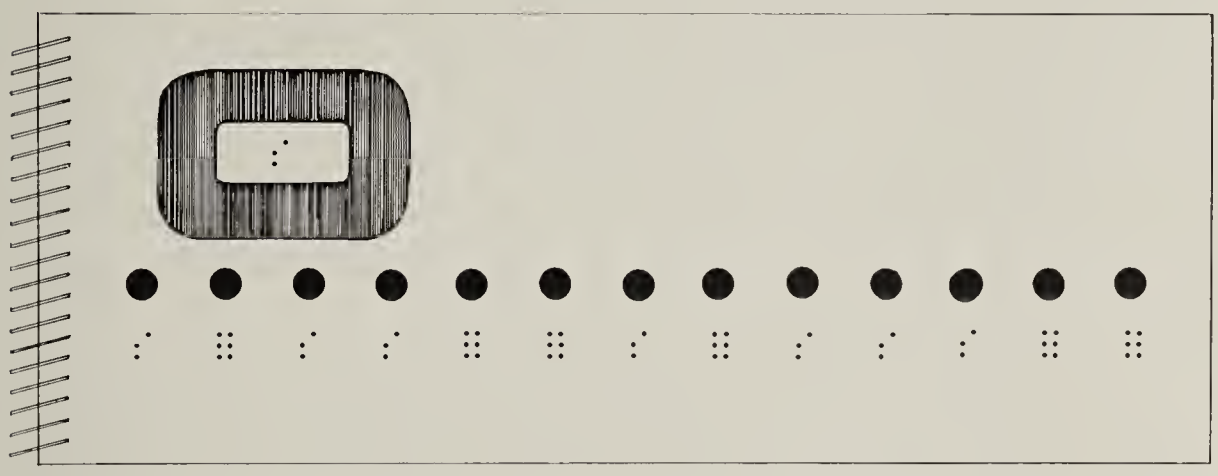
Suggestions on Technique

The following are general suggestions for making pop sheets:

- The area of pop sheets for mathematics and for braille characters can be enlarged by taping several pop sheets together. The area can be decreased by removing several rows of dots or cells, making it possible to make individual words, letters, or mathematical problems.
- Pop sheets can be used over and over again by simply pressing up the indented dot on the back of the sheet.
- Cut a braille pop sheet into individual braille cells. Press down similar letters and letters that look almost the same on an uncut pop sheet. Find the letter that matches the letter on the pop card. The same training method can be used for braille numbers: Cut out cards containing two or three braille cells, allowing one braille cell for the number symbol.
- Pop sheets and answer cards can be ordered from RPH-SYN.

Recognition Books

There are many uses for the embossed dot system. One is a recognition book for children in which items are identified by dots (for example, see Lindblad, 1976). The item to be identified is placed inside a frame. Below the frame, a single row of embossed dots stretches across the page. Below the dots are symbols, characters, or figures, several of which are identical to the item within the frame. The child presses down the dot over those items that are similar to the one within the frame.



Items and corresponding dots in a recognition book.

A frame of Con-Tact paper or sandpaper can be added to the plastic copy after it is vacuum formed, or it can be included on the master, depending on how you want the book to feel. A tactile experience of actual material added to the plastic makes the display more interesting and allows for more variation in the material used for the frame.

WIRE AND METAL MASTERS

Wire and metal masters are used in many countries as masters for vacuum-forming machines or as displays in their own right for orientation maps of buildings and areas inside or outside of public buildings. They are not affected by weather or use. Copies made according to this method feel similar to those made with the string techniques, but they are more durable than the paper-and-string buildup, and the line symbols may make a sharper imprint in the plastic copy than the string variety makes.

The background material is metal, and the line symbols are formed by solder wire. The solder can be used in its original form, or it can be rolled with a triangular cross section to give

dotted or dashed lines. Dots of solder along the line can also change its character. They are not affected by weather or use. Copies can be made by placing slightly dampened paper over the master and forming the copy under great pressure.

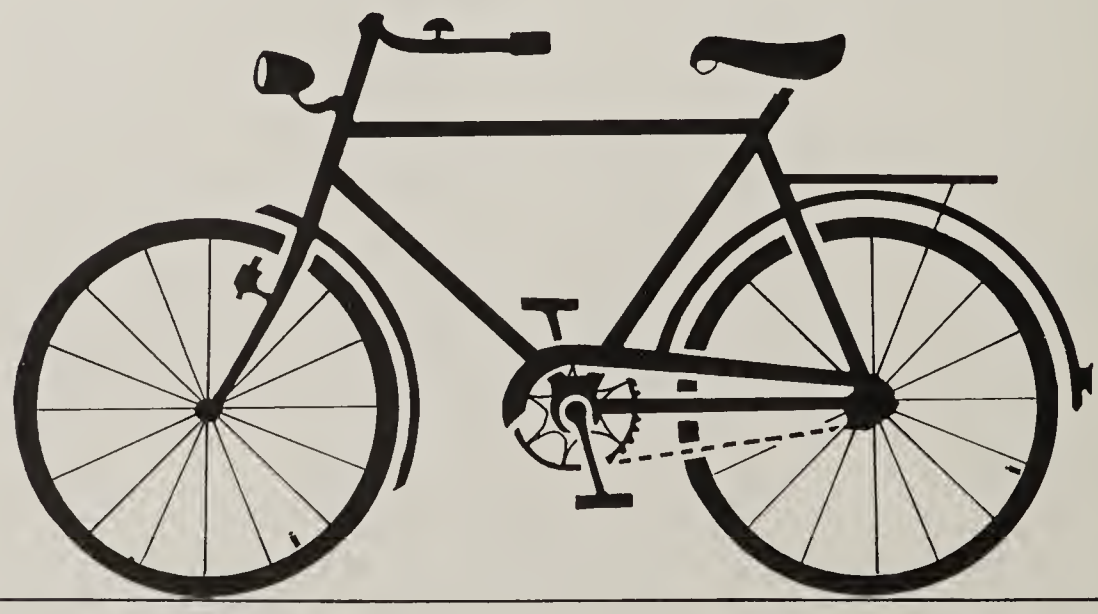
Soldering is time-consuming and demands skill. However, for large series of tangible graphics, it is an economical method. In addition, the master requires very little upkeep.

MICROCAPSULE PAPER

Microcapsule paper, which expands when heated, is a quick and economical material for producing one or many simple relief displays from a printed diagram or an original drawing. Microcapsule paper graphics are excellent for low vision as well as blind readers. The simple black-line reliefs can be read easily with the eyes as well as the fingers.

Microcapsule paper is standard white paper that has been coated with millions of microscopic plastic capsules. The display, printed on the paper in black, expands when it comes in contact with a constant heat of 248°-257° F (120°-125° C). The microcapsules beneath the black lines of the diagram absorb more heat than the other microcapsules and expand to a greater extent, which results in raised lines, areas, and symbols.

Black-and-white graphic material—original drawings or printed matter—can be copied onto a sheet of microcapsule paper by using a photocopy or office copying machine that has a manual feed so that sheets of paper can be inserted into



A master for the expanding paper process—microcapsule paper.

the machine one at a time. (It should be noted that halftones are difficult to reproduce.) The machine should be able to handle paper with a thickness of .010 in. (.25 mm). When the graphic display is transferred to the microcapsule paper, it will expand immediately *if* the copy machine operates with carbon-based toner and is equipped with an infrared heating unit. If the machine is not equipped with a heating unit, take the printed, unswelled microcapsule paper copy and insert it into an offset heater or fuser. The display will expand in a few seconds.

One can draw directly on microcapsule paper. The paper can then be inserted into the heater or fed through the photocopy machine, provided it is the type of machine that can expand the diagram; the display will immediately be raised in elevation. For displays made directly on microcapsule paper, use felt-tip pens with an alcohol and carbon base (these pens usually have a strong smell), black wax crayons, or lead pencils. Water-based felt-tipped pens will not swell directly when heated but are fine for making a display on which paper will be copied onto the microcapsule paper in an office copying machine.

One of the great advantages of microcapsule paper is that you can add information to an existing display. Draw the desired lines or symbols directly on the expanded paper display. Run the paper through the heater once more. The new information will become part of the relief, and the two elevations will be the same. The paper can be reheated two or three times before it will loose its sharpness. However, it may be necessary to reduce the heat of the heater at the second or third swelling.

The life of a microcapsule paper display is more limited than that of a vacuum-formed plastic copy of a display. This fact should be taken into consideration when there is a possibility that the relief map or picture will be used out of doors. When the microcapsule paper becomes damp, it eventually disintegrates, as will any standard paper.

Microcapsule paper can be stored in a dry area at temperatures between 32° and 95° F (0°- 35° C). However, since microcapsule paper expands when heated, do not send excess waste paper to a paper-recycling plant. Microcapsule paper will swell during the recycling process and clog the

plant's machinery. Destroy scrap paper with other waste products.

Microcapsule paper manufactured by Matsumoto Kosan Company Ltd. in Japan is made to be used in the Matsumoto Kosan or Minolta Stereo Copying Systems. It can also be used in an office copying machine and the illustration swelled in an infrared heater, as explained later in this chapter. Both paper and machines are distributed by J.P. Trading. The paper is also available from RPH-SYN, which formerly produced a similar paper called Swell Paper. (See "Sources of Materials and Equipment," Appendix 3 for addresses.)

About Technique

The elevation of the relief is only variable through heat. Approximately the same low elevation is constant throughout the display and is slightly higher than the size of a standard braille dot. (If it exceeds this height, it has been overheated, and the lines and shapes begin to lose their sharp contours.) Therefore, it is necessary to keep in mind that the distance between lines or forms, symbols, and braille text should not be less than .2 in. (5 mm) to enable the reader to understand them as individual items.

When drawing an original display or retouching a printed diagram for reproduction, be sure that all lines and shapes have sharp, clear-cut edges. This is especially necessary for comprehension of this one-elevation material.

Black Areas and White Areas

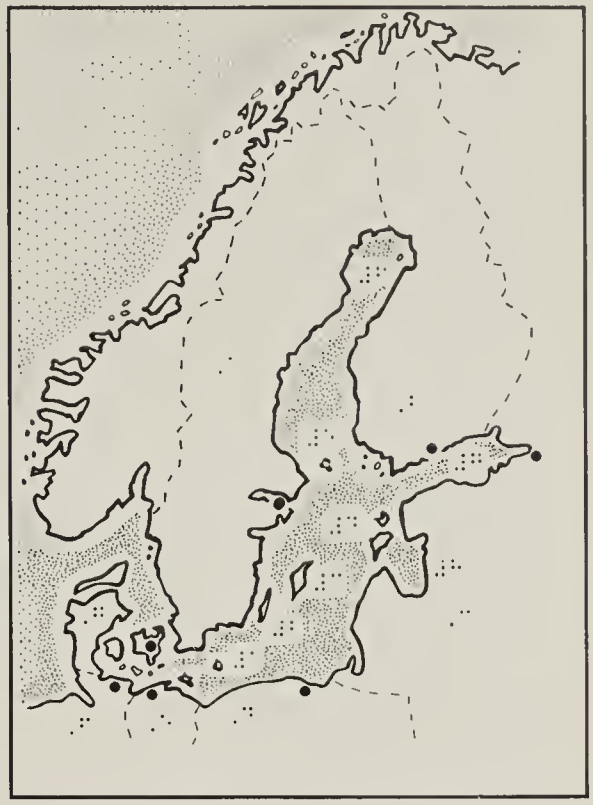
For large areas of black, use a dense line texture instead of a solid black area (see A and B). When a large, solid, black area swells, it often warps the paper and hinders comprehension. Textures adjacent to lines or point symbols and symbols adjacent to braille require an area of white around or along the area of black print in order to enable the reader's fingers to adjust to the changes of form in the display. (For examples, see C, D, E, and F.)

A.

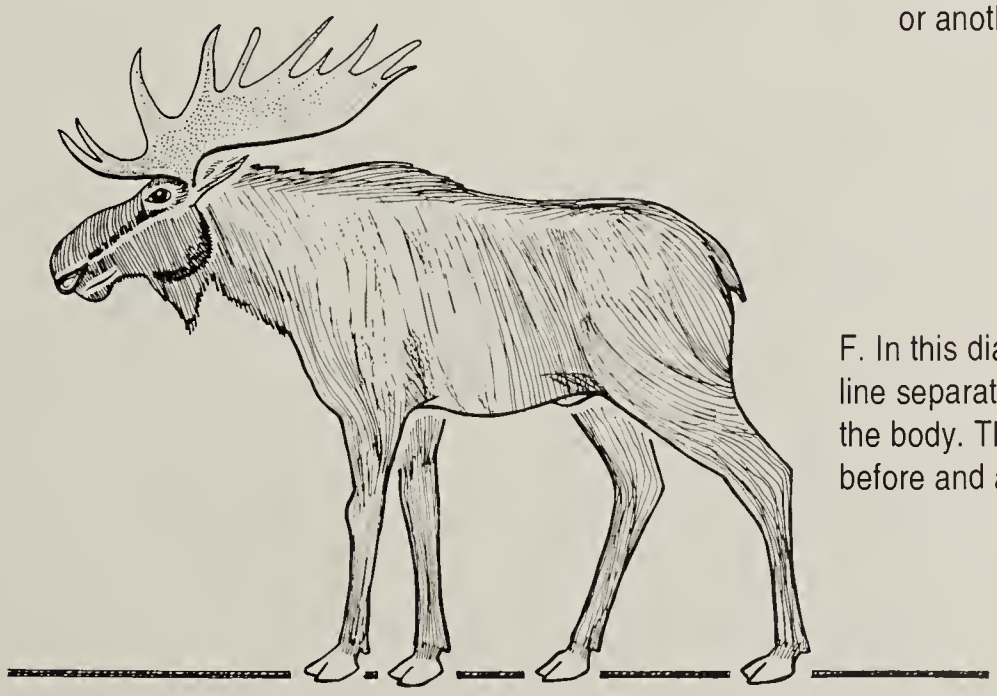
B.

C. In this map, the wide, black line designating a road stops for the white area surrounding each of the dots that represent a city. Lines for the coast stop to allow white space around dots for coastal cities.

D. In this map, the dotted texture, a symbol for water, stops before reaching the black coastal line of the continent.



E. In this map, white space is left around the braille characters so that they stand out in a textured area. The braille characters have been placed within a dotted area, a potentially confusing situation that should be avoided but can be used if necessary if enough white space is left. In this map, it would be advisable to change the texture of the water from dots to lines or another form.



F. In this diagram of an elk, a white line separates the elk's legs from the body. The reference line stops before and after each hoof.

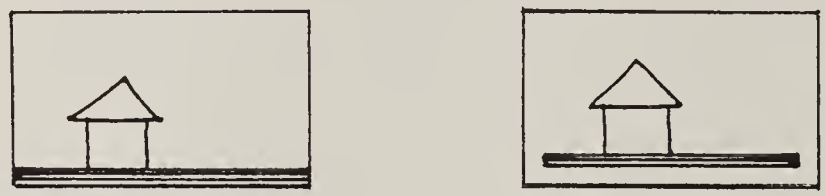
Width of Lines

Wider lines mean darker lines. They will feel more important in a display than thin lines, as they give the impression of being more elevated. Some textures can be used next to wide lines without an adjacent white area (see "Line Symbols," Chapter 6).

It is advisable to test textures and lines both together and separately before using them in a final display. Not all graphic material feels as it looks. Textures that look completely different may feel alike when they are expanded in a one-elevation relief (see "Areal Symbols," Chapter 6). Remember, *all* black areas swell when heated. A textured area will not feel as high as a solid black area. An indented area, a hole, should never be black, because the supposed indented area will turn out to be raised.

Size of Layout

Keep the original layout for the display smaller than the actual size of the microcapsule paper. Lines and textures that come to the edge of the paper often make the paper curl when the display is heated (see A). Leave a minimum of .4 in. (1 cm) between the layout and paper edge (see B).



A. B.

Color

The addition of color is recommended for readers with low vision, both as an aid to comprehension and as an added reader activity if students are working on the display. Color can be added to the display *after* it has been swelled. Felt pens and crayons are good for this purpose. Test water colors before using them on a final display—they may dissolve the microcapsule coating on the paper.

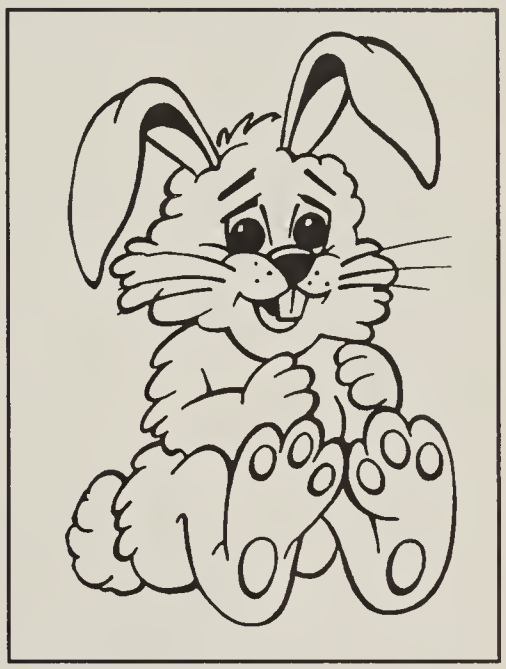
Printed Text and Symbols

Special sheets of instant lettering in the form of hundreds of braille cells that can be dry transferred to the original graphic layout are available from RPH-SYN. When swelled, these braille cells will expand to the same size and height as standard braille (see "Labels," Chapter 6).

Textures, lines, and inkprint letters are available from art-supply stores in rub-on sheets or tapes from a variety of

producers. Letraset and Mecanorma are companies that offer the largest assortment.

Instant dry-transfer lettering, symbols, and textures should be added to a black-and-white printed layout before it is placed in an office copying machine and printed on a sheet of microcapsule paper. If these transfers are added directly to the microcapsule paper, they will swell to an acceptable height but they will probably not retain their original appearance. The transfers are printed on a thin film that often burns away during the heating process, taking with it the black print of the relief forms. There seems to be some reduction in the sharpness of the edges of the forms as well.



This rabbit is a cartoon drawing. It has an oversized head, foreshortened legs, and arms lost in a confusion of lines and a figure in perspective. The overall impression this figure gives to the blind reader when it is printed on microcapsule paper is that it feels like a plate of spaghetti.

Editing

When working with microcapsule paper, one must consider all the principles involved in creating tangible graphics. Many of the available maps and book illustrations are not suitable for the blind reader and should be edited or completely redrawn. This is especially true when working with single-elevation reliefs.

When editing inkprint pictures, maps, diagrams and charts for a microcapsule display from an acceptable original display, remember:

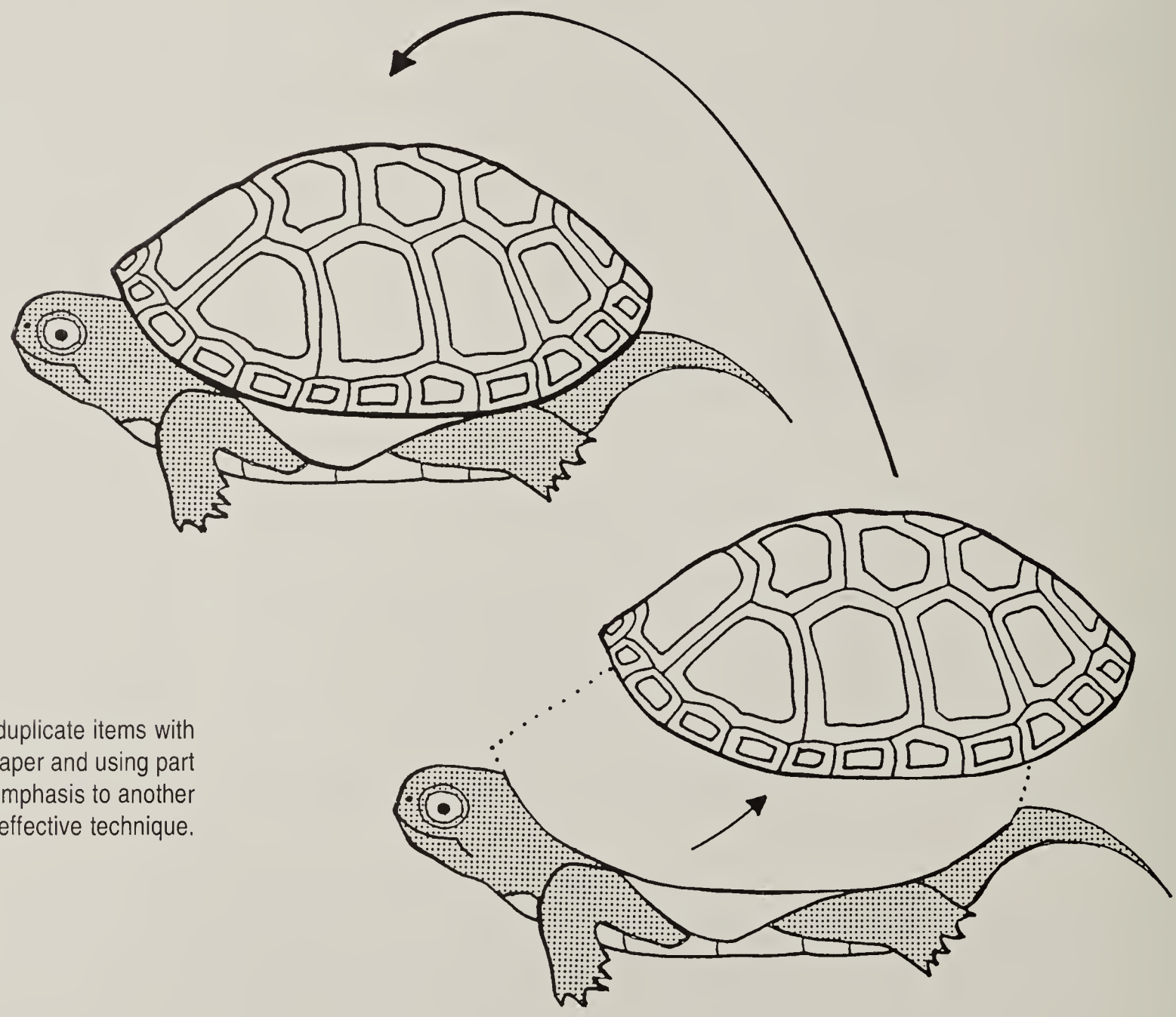
- Make lines thicker and thinner, depending on their importance in the display.
- Retouch with black ink those places where lines or texture are missing due to the printing and enlarging process.
- Reduce clutter by masking undesirable elements with white paint or correction tape.
- Lines and arrows, so prolific in printed diagrams, may need to be moved or deleted.

Special Emphases

Special emphases can be gained with a microcapsule paper display. This technique is useful with illustrations or with maps and emphasizes a particular area of a display by raising it above the rest of the display. It can be done quickly by using cardboard, scissors or a scalpel, and glue. The result is very effective.

Here is an example of how to add special emphases on a microcapsule paper display, using the two turtles shown:

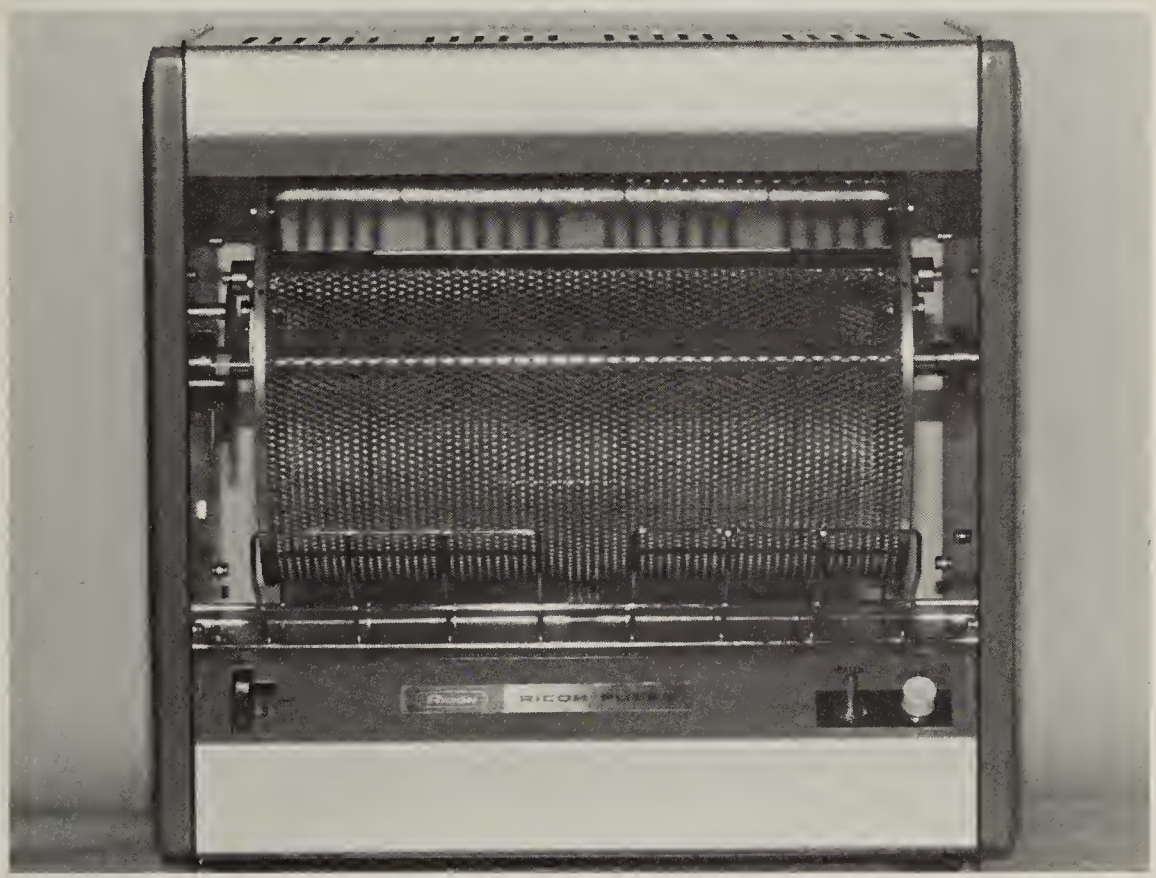
1. Make two copies of the turtles on microcapsule paper.
2. Swell both illustrations in an infrared heater (see below).
3. Spray glue on the back side of one turtle.
4. Mount that turtle on a piece of cardboard.
5. Cut out the cardboard-backed turtle shell.
6. Spray glue on the turtle shell and mount it on top of the second turtle's shell. (Note that the height of the added part of the display is regulated by the thickness of the paper or cardboard to which it is glued.)



Making duplicate items with microcapsule paper and using part of one to add emphasis to another is an effective technique.

The type of infrared heater-fuser shown on the next page expands the displays printed on microcapsule paper within a few seconds. Microcapsule paper should be removed from the

fuser as soon as the heat snaps off and then placed on a flat surface to cool. This will keep the paper flat and eliminate the tendency for the edges to curl. The cooling process is almost instantaneous. The machine is available from RPH-SYN or from suppliers to the printing industry throughout the world, since it is often used in offset printing.



Infrared heater used to expand displays on microcapsule paper.

ELECTROFORMING PROCESS

The electroforming process is a method for accurately reproducing the surface forms of various materials on a sheet of metal. This process is not widely used and cannot be undertaken without much more information (see Goto, 1983, for more information) and special equipment and techniques beyond those mentioned here.

However, the process should be mentioned as a possibility, considering the increasing need for signs and guideposts containing information for visually impaired persons in such areas as train or bus stations. The special requirements imposed on these displays to withstand weather, excessive use, and vandalism are demanding.

The preparation of a master for the electroforming process is similar to that of one to be used in a vacuum-forming machine—various materials are glued to a background sheet. A silicon rubber negative mold is made from the master. The

In a tactile map at the Omiya Station outside Tokyo in Japan, different objects, such as railroad entrances and exits, restaurants, and newsstands, are represented by different textures.

inside of the mold is painted with graphite to make it conductive. Materials that may stick to silicon rubber must be sprayed with lacquer. Cut ends must be tapered off and fortified by soaking them in cyano acryle. Braille dots laid on a coarse surface should be inlaid.

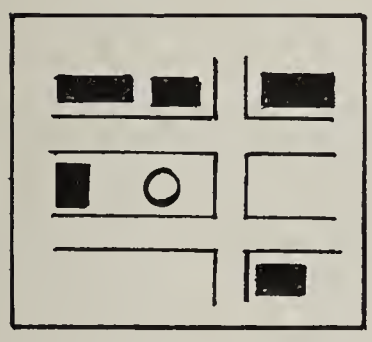
The process of electrodeposition is almost the same as electrogilding. The silicone negative mold is put into the liquid copper sulfate at the negative pole, and the copper piece is connected to the positive pole. The poles are charged for 48 hours, after which a copper deposit of .08 in (2 mm) thickness can be separated from the surface of the silicone mold. Any surface areas on the copper that could cause tactual discomfort can be smoothed down by the use of sandpaper. The mold is then finished with nickel chromium electrogilding.

The Odensha Company has made excellent use of the electroforming process to create metal displays for public places. Further information can be obtained by contacting the company at 316 Kamihirama, Nakahara-ku, Kawasaki City, Japan 211.

NYLOPRINT

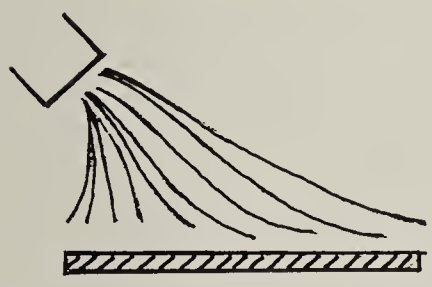
Nyloprint is photoengraving of metal or nylon plates with the aid of photography. This process is based on sensitized gelatin impregnated with bichromate of potassium, which becomes insoluble under the action of light. The gelatin is flowed onto a copper or nylon plate. The plate is exposed to light under a

photographic positive of a map or picture. The protected and still-soluble coating of gelatin is washed away. The remaining gelatin is insoluble and hardened, and it forms part of the relief pattern on the plate. The following are the steps in this process:

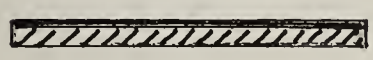


1. A black-and-white drawing that shows every line, dot, or area that should be in relief on the final plate is prepared. The drawing is photographed on a film negative. It can be enlarged or reduced during this process.

2. The plate, which can be made of metal or nylon material, is placed in position.

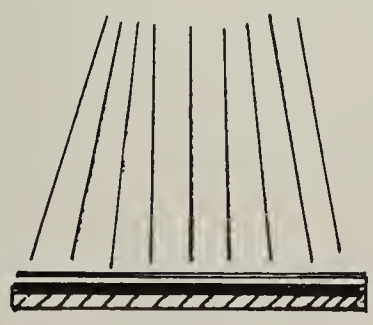


3. Gelatin is flowed onto the plate.



4. The plate is covered with gelatin.

5. The film negative is placed on top of the prepared plate.



6. The plate is exposed to light, which hardens the surface of the plate at those areas where it passes through the negative.

7. The negative is removed and the gelatin is washed away with menthol alcohol or water. Those areas not exposed to the light are thus removed.

8. The remaining surface of the plate shows those symbols painted black on the original drawing as elevated areas.

9. If necessary, additional information can be glued to the final plate.

As both a positive and negative of the photographic transparency of the required pattern can be obtained, a corresponding male and/or female plate can be produced to be used for paper relief displays in a printing press or pressed under pressure. This process is used for producing ordinary printing plates photographically and is utilized in several European countries for making relief material for visually impaired persons. Some maps can be made on photoengraved metal plates.

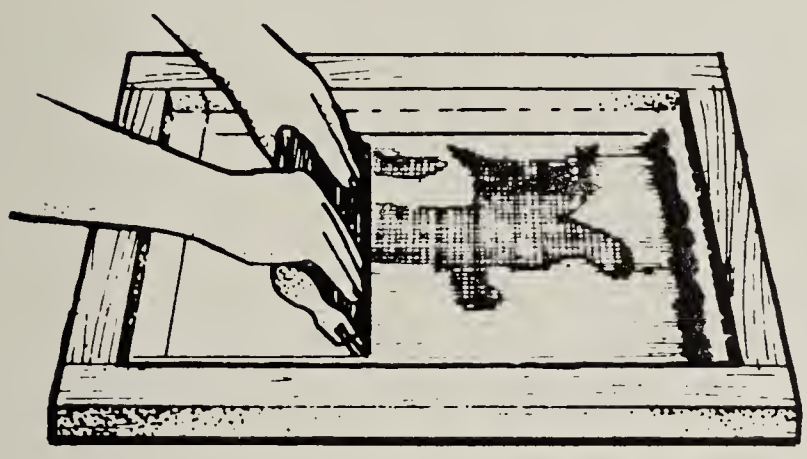
SILK SCREENING

Silk screening is a simple and economical form of printing using stencils. A stencil is a piece of thin sheet metal, plastic, or paper so perforated that when it is laid on a surface and color is applied, a desired figure is produced on the underlying surface.

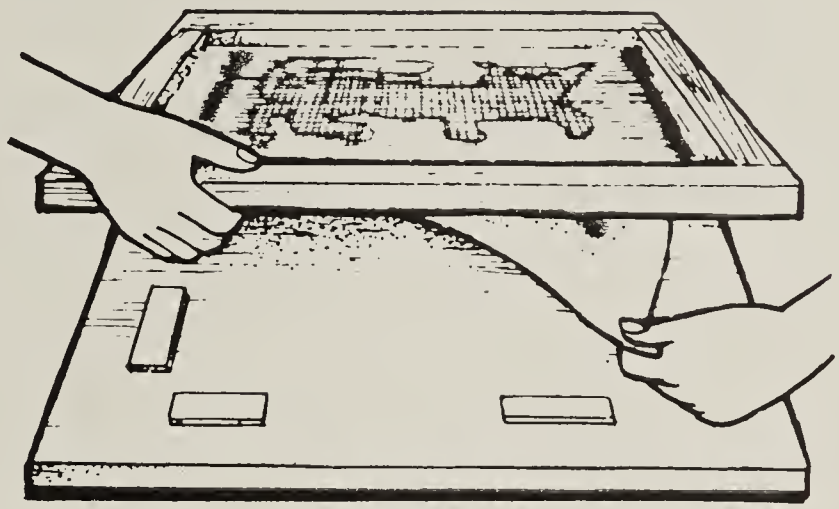
The silk-screening process is as follows:

1. Finely woven material (silk or synthetic) or fine screening is stretched tightly over a wooden frame.
2. The stencil is placed over the screen so that certain areas are masked off or covered.
3. A background material, such as paper, cardboard, or plastic, is placed under the screen.
4. Color is applied to the surface of the screen. A squeegee is

used to spread the color evenly (see A). The color passes through the unblocked areas to produce the desired design on the underlying background material. The background material is removed from beneath the screen (see B).



A.



B.

Note that the stencil can be omitted if a drawing is made directly on the silk screen and all areas that are to be masked off are painted with sizing, which is a glutinous material prepared from glue, flour, or varnish and used to fill the pores in the surface of the screening material so the color will not be able to pass through the pores.

Silk-screen displays have been produced for sighted people for many years. The relief aspects of this process have also been found useful for visually impaired persons because of the thickness of the color on the printed surface.

Relief Maps

Another important use of the silk-screen process is in the production of relief maps. The process is as follows:

1. The original drawing of the map is transferred to one or several screens, depending on the different areas and colors to be printed. The masking process is done directly on the screen or with stencils.
2. The same original drawing is used as the basis for the master for the relief.
3. These two components—the flat silk-screened display and

the master for the relief—must be made to fit each other perfectly.

4. The map is silk screened onto a plastic sheet. This sheet is then positioned exactly over the corresponding areas on the relief master that has been placed in a vacuum-forming machine (see "The Vacuum-Forming Method," this chapter).

Note that paint or ink that is to be used in this process must be tested so that you know how it will react when it is heated. The printed plastic may also shrink a maximum of 10 percent when it is formed over the master for the relief.

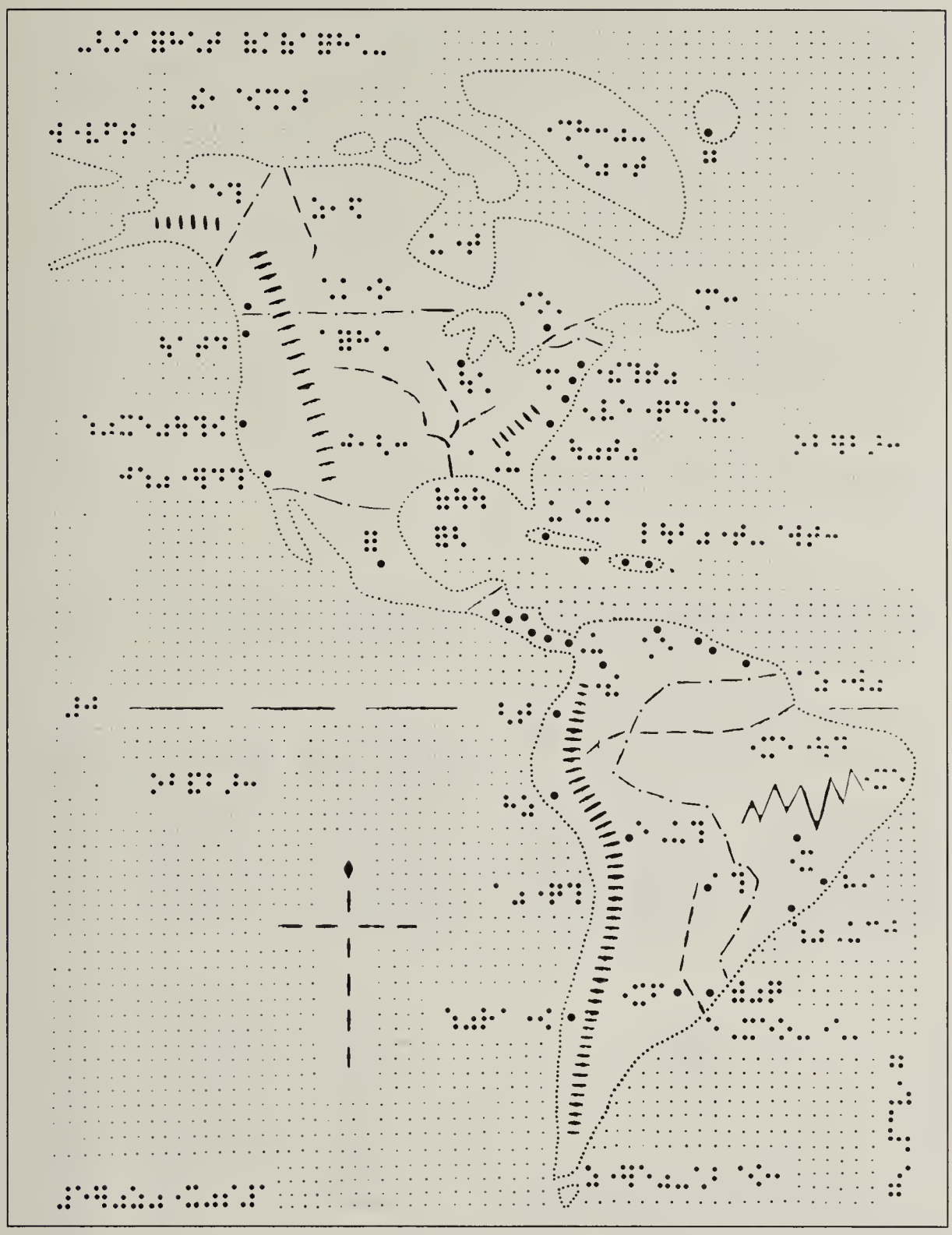
As is evident, much time and experimentation go into making an acceptable product. However, the end result is a relief map that is usable for both blind and visually impaired people.

The Solid-Dot Process

Nippon Lighthouse in Japan developed the solid-dot process technique for mass-producing screen-printed embossed maps on paper. The advantages are that no special equipment is required, the process is inexpensive, production is on paper rather than on plastic, and multicolored maps can be produced by using a variety of different colored paints. Maps made using this process are good for people with some useful vision who use both their visual and tactile senses to read maps. The disadvantages are the low elevation of embossed areas and the difficulty of obtaining dots of a uniform size and shape.

In England, RNIB experimented with a printing system of raised plastic dots produced on braillewriter paper in which the plastic "paint" was extruded through metal dots onto the paper. It was hoped that this process would be an inexpensive method of mass production. Unfortunately, the dots flaked off the paper, and RNIB stopped using this technique.

A method being developed at the Simon Fraser University uses the silk-screen process with various materials of different tactile qualities scattered onto wet, freshly applied colors, so that the materials stick to the paper base as the colors dry. (For further information, contact Ray Squirrell, Simon Fraser University, Burnaby, British Columbia, V5A 1S6, Canada.)



Screen-printed embossed map using the solid-dot process, from a Japanese atlas made for visually impaired elementary school children by Nippon Lighthouse.

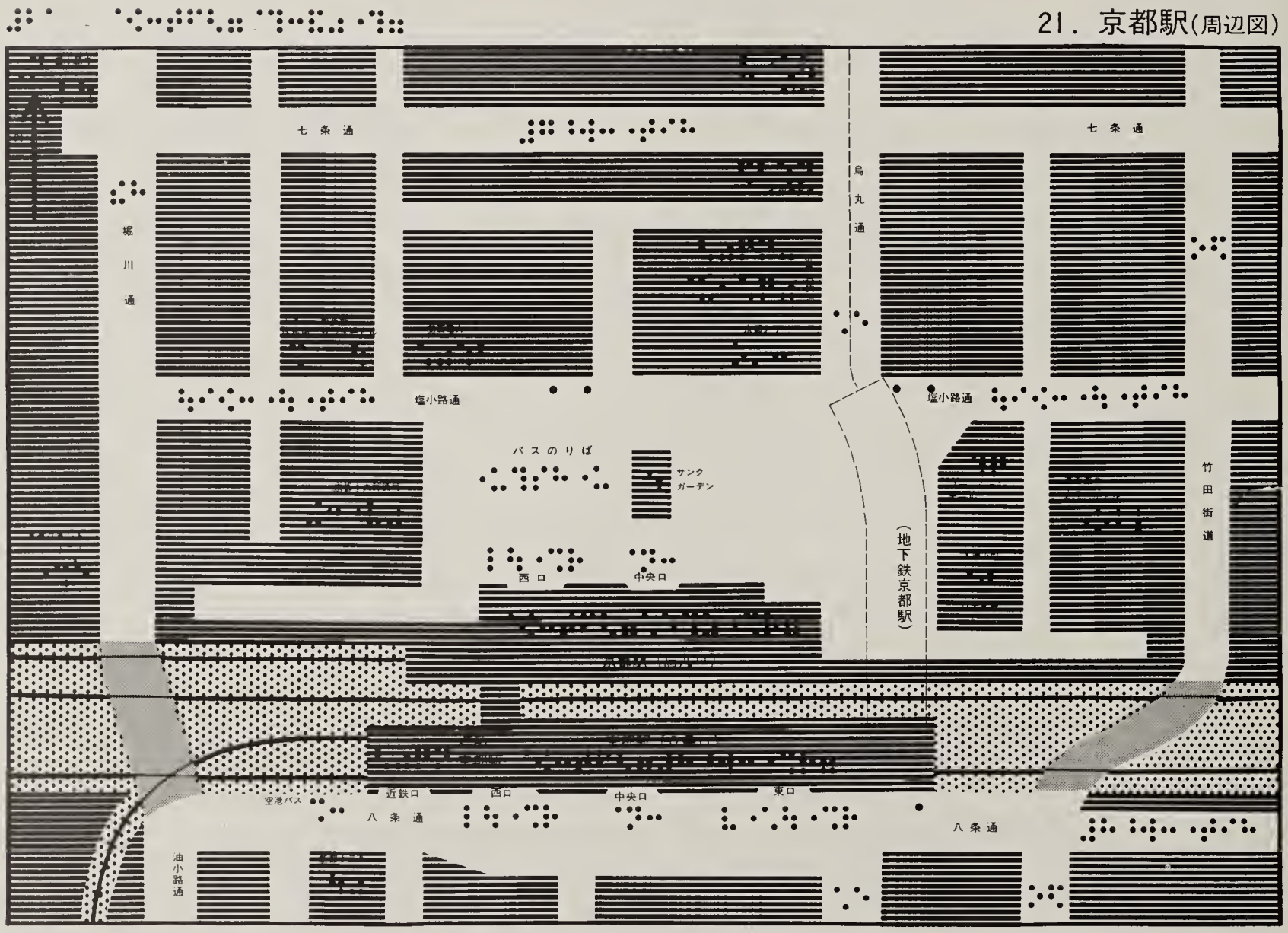
Foam-Ink Printing

This method employs the silk-screen-printing process. The ink is mixed with a foaming agent. When the printed paper is exposed to heat, about 130° F (55° C), the letters or forms expand, giving the display a good tactile character.

The advantages of this method are as follows:

- It is suitable for mass production.
- Two elevations in printed matter can be obtained.
- The ink can be printed in several colors for use by low vision readers.

- Both sides of the paper can be printed in relief.
- Inkprint letters can be printed in offset on the graphic display so that sighted people are able to help visually impaired people read a display.
- The size of the display is not limited to the dimensions of standard braille paper. Silk-screen printing is often used to print posters and other large materials.
- The background material is paper as opposed to vacuum-formed plastic. Many people prefer the "softness" of touch when using material made in this way. They believe that plastic tends to desensitize their fingers.



Map made with the foam-ink technique, appearing in *The Guidebook for the Visually Handicapped Using Public Transportation Facilities.*

One drawback is that the height and control of a line may depend on the thickness of the screen used in the silk-screening process and the coarseness of the ink. Therefore, it may be necessary to let the ink stand for several days to obtain the desired results.

This method is used in Australia and Japan. (For further

information on the special inks involved, write the Japan Braille Library in Tokyo.) The foaming agent is made by Toppan Printing Company (see "Sources of Materials and Equipment," Appendix 3 for addresses).

The Guidebook for the Visually Handicapped Using Public Transportation Facilities, published by the Ministry of Transport for the Japan National Railway, was printed in Japan with the foam-ink technique. Graphics are printed on the right pages and the explanation in braille is printed on the left pages. There is print on both sides of all pages.

The relief is made in two elevations. A matte-blue color, which includes the braille characters and most of the symbols, is the highest print. A matte-orange color, which covers most of the areal texture, is somewhat lower in elevation. The Japanese characters, printed in light gray, are not in relief.

The Kiwoprint Technique

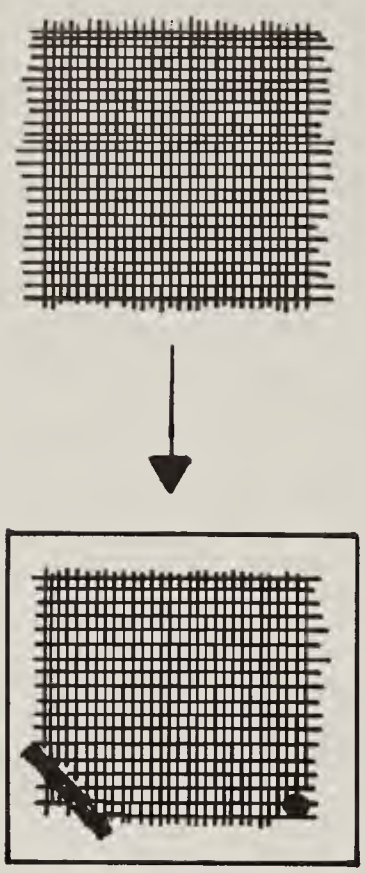
The Kiwoprint technique is a screen-printing process using Kiwoprint 300, a foam-forming printing paste. It is a medium for the easy, economical reproduction of braille characters and tactile-graphic displays on various surfaces. It is capable of providing high and variable relief in a range of colors and is easily read because of the clearly defined edges it produces.

If the paper is printed on one side, the print should be cured (heated), foam side up, for one to two minutes at 356-365° F (180-185° C) immediately after the printing process. If the paper is printed on both sides, heat (fix) it one minute at 284° F (140° C) immediately after printing the first side. Then reverse the paper and print the other side, heating that side of the paper one to two minutes at 356-365° F (180-185° C).

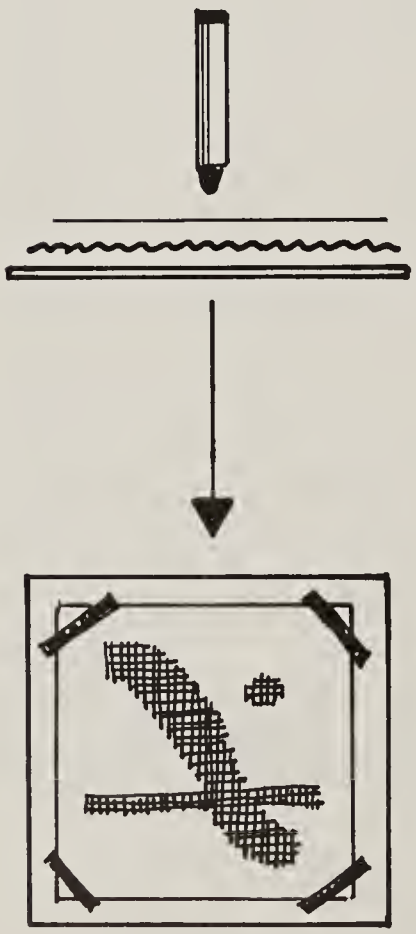
It is possible to overprint Kiwoprint several times with fixing in between each printing at 284° F (140° C). Overprinting results in a variation of heights after the final curing for one to two minutes at 356-365° F (180-185° C). (For further information, contact Kissel & Wolf; see Appendix 3 for address.)

Storm Relief Printing

Storm relief printing is a system of printing tangible graphics on an offset machine. The printing ink swells when heated. The United Nations Educational, Scientific, and Cultural Organiza-



A.



B.

tion (UNESCO) has used this process to produce books that are to be read by sighted and blind children together. The method and machines were invented by Storm & Company, Odense, Denmark (see "Sources of Materials and Equipment," Appendix 3 for address).

Screen Drawings

In the screen-drawing process, the relief drawing is made with a wax crayon on a sheet of newsprint paper that has been placed on top of a wire or plastic screen. The screen is fastened to a firm background or taped onto a tabletop. It could, for example, be attached to a masonite or thin wooden board with thumbtacks or tape (see A). When the wax crayon is drawn across the screening, it leaves a raised wax image on the paper (see B). Lines can be varied only in width and length, and forms only in shape and size. Texture is not variable unless more than one wire screen is used—the first screen is then replaced by a second screen of larger or smaller wire dimensions and larger or smaller spaces between the wires. However, using more than one screen is not really worth the effort.

Both sighted and blind persons can use this medium. It is a very inexpensive and excellent way to explain uncomplicated mobility problems in relief—the layout of a room, a street crossing, or a simple map. Materials are easily available at hardware stores and paper shops.

COMPUTER GRAPHICS

Computer graphics systems are being developed at a rapid rate. These systems will give blind people access to a tremendous variety of graphic material.

Computer graphics enable one to enlarge or decrease the size of any given object or display immediately and to select quickly the particular areas of the object to be enlarged, decreased, simplified, or broken down into a step-by-step display. In addition, the planes of the object can be rotated and presented from many different angles, thus enabling the producer to choose the most understandable way to make a tangible display for a blind reader. Original displays can be stored for later retrieval and for changes and addition or

deletion of information. Computer techniques are especially useful in map work, in which one basic map may be changed innumerable times within a matter of minutes.

Computer-Aided Production of a Master

Work on computer-aided design for a map layout was begun in 1972 by J.M. Gill of the Research Unit for the Blind in Uxbridge, England. Development of Gill's work was taken over by the Computer Center for the Visually Impaired at Baruch College, the City University of New York, in 1980. The components of the system were described as follows (Luxton, 1983):

> The system has three major components: an input digitizer for two-dimensional graphics; an intelligent terminal with CRT (cathode ray tube) display; and a servo-controlled three axis engraving table. The terminal includes operating and executive programs, drive software for input and output, and stored data for symbols, braille and elementary lines and shapes.

The system requires several steps, five of which are done by the computer and two of which concern the production of the relief diagram. Creating, modifying, viewing, and storing on a disk and engraving or carving the drawing into a hard-plastic base material by a motor under the engraving table are computer tasks. The result is a hard-plastic negative master into which silicon rubber is poured. The hardened rubber is peeled from the negative master and has a positive surface that can be used in a vacuum-forming machine for producing copies of the graphic material.

A similar project was started in Sweden by Peo Krook in 1990. The advantage of this system is that different objects on a map can be carved into the base material at several different levels, which are not confined to one raised elevation and one incised elevation. The result is a three-dimensional display. Large areas can also be made solid areas and are not portrayed by outlines alone.

The software that is used in this system is a standard program, a computer-aided design type: AutoCad or MicroStation. The three-dimensional milling machine is driven by the computer. The negative milled master, which has been programmed, is then transformed to a positive master by a

silicon coating and the resulting vacuum-formed plastic copy has a sharp and varied surface. (For further information, contact Peo Krook Dataservice, Box 47104, S-100 74 Stockholm, Sweden.)

Computerized Production of Tactile Graphics

The technical development of computers has advanced rapidly. New, better, and more economically priced hardware (computers, printers, terminals, and so on) and software (computer programs) are constantly being introduced on the market. This is also true concerning new methods for the production of tactile graphics. All computer-aided methods for producing tactile graphics can be divided into three steps: input, editing, and output.

Input

To produce a display, information concerning the components of a picture, map, or diagram must be fed into the computer. This can be done by using the following methods:

- Drawing directly on the computer screen with a light pen or a mouse. A light pen is a penlike input instrument that is used to give commands to the computer instead of using a keyboard. A mouse is a small input instrument that is easily moved over a flat surface and indicates your present position on the screen.
- Transferring an original picture, map, or diagram by using a coordinate or crosslined board and a digitizer, a special pen that sends impulses to the computer when pressed against a specific point on the crosslined board.
- Transferring an original illustration by using a scanner, a tiny camera that comes into direct contact with the printed illustration and transfers its image onto the computer screen.
- Utilizing a digital television camera that can take a picture from a distance and transfer it to the computer screen.
- Transferring digitally stored graphic information from one computer to another.

Editing

Digitally stored graphics are retrieved and brought up onto the computer screen, where information in the form of words, lines,

and textures is added, enlarged or diminished, rotated, moved within the illustration or deleted, as is necessary for reader comprehension.

Output

The finished illustration can be transferred to some media that can be used to produce relief material for visually impaired persons. The following are examples:

- A braille printer that prints braille relief on paper.
- A plotter (a drawing machine) or laser printer (similar to a copying machine) that prints the image on microcapsule paper. This paper is then put into an infrared heater to swell the printed area into a relief display.
- A computerized milling machine that engraves a positive and/or negative master that can be used in the vacuum-forming method or to produce a one-of-a-kind relief display.

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CHAPTER 3

Display Requirements

The ability of the eye to distinguish shapes and patterns, to discern forms, understanding them through association, background knowledge, and repetition, is vastly superior to the fingers' ability to recognize these same shapes, patterns, and forms produced in a tactile display. Sighted people can sift out visual impressions that are immaterial. Blind people, however, read every line, dot, and texture that comes under their fingertips. Ignoring "visual" impressions is not a possibility for them. Remember this distinction; it is vital!

BASIC PRINCIPLES

It is up to those of you who produce relief displays to make them as clear as possible, always keeping in mind the point of view of the blind reader. There are several distinct ways in which to do so:

- By knowing the framework for a display—the facts to be kept in mind when creating a relief display.
- By being familiar with the capacity, knowledge, and background of the reader or readers.
- By carefully editing the printed display before making it into a tactile display.
- By proofreading the results of your work—the original, master, and copy—with your *fingers*, not your eyes.

In the chapters that follow, principles and methods relating to a wide variety of tactile graphics are discussed. Much of the

OPPOSITE PAGE: The object of tangible graphic displays is to present many different types of information to blind and visually impaired people in the most understandable way.

information in these chapters overlaps, as it should. The object of tangible graphic displays is to present many different types of information to blind and visually impaired people in the most understandable way.

Presented here are suggestions, not rigid rules. I and others have found these solutions to be acceptable and applicable. However, you may find different solutions for the construction of your displays. Keep an open mind. Work with your readers; listen to their comments and suggestions.

A first principle to remember is one that has already been mentioned: variation in height is the trait of a relief display that gives the greatest amount of information to the blind or visually impaired reader. This observation may influence the construction of your display. It may also determine the choice of the production method to be used. Simple line drawings, outlines, geometric figures, and graphs may be easily understood in a single elevation above the background surface. An embossed line drawing or a display produced on microcapsule paper is sufficient in this case. More complicated displays with several elevations may require more time, effort, and equipment. Irrespective of the method you choose, keep the 1/8 in. (3 mm) limit constantly in mind. There should be a space of 1/8 in. (3 mm) (the approximate distance between two braille cells) or more between lines, symbols, textures, arrows, labels, and shapes so that the display is easy to read and comprehend.

After you have decided what you are going to do, for whom you are doing it, and by which method your tactile graphic display will be produced, the next step is to decide on display requirements such as what shape it will take and its size. Since these decisions involve both the overall format and the scale of the display, they must be made before you begin work on your graphic layout.

SIZE

There are many conflicting views about the best size for tactile graphic displays. Since it is known that fingers are not as good as eyes in discerning small objects, some people advocate making large displays so that readers can understand what their fingers are feeling. But, say others, small displays are better than large ones because they allow the reader's fingers to take in as much as possible at one time. Many people believe

that a tangible display should be kept within a hand span—the distance from the end of the thumb to the end of the little finger when extended. Still others prefer an area the size of two hands, with thumbs barely touching and fingers spread out.

The decision is up to you, depending on the content of your display. Small displays with a great deal of information tend to become cluttered and confusing. They should be enlarged or broken down into several displays. If your project is an overall picture or map, make a small-scale, uncomplicated display with an emphasis on simplicity. Follow it with a larger scale display that clearly defines the different areas of the display.

The ideal layout should lead the reader through the maze of lines, shapes, symbols, and textures with the least amount of effort, allowing him or her to locate quickly the important information that is presented.

The reader is a very important element in the choice of content, size, and scale. His or her mental age and ability, background, knowledge, and familiarity with reading tangible graphic displays must be determining factors.

To get the most out of reading a relief display, a person must be trained to use his or her hands. I became aware of this when I was working with young blind children in a class on form many years ago. How necessary it was to have the children use both hands when they felt an object! Louise Zeuthen (1976, p. 47), a physiotherapist, has explained why this is so: "If (a child) is given a wooden spoon...and he takes the spoon with one hand, it is not a spoon for him, but only a piece of wood. With hand-hand coordination, it is possible for the child to feel the real shape and size of the spoon." This observation is also applicable to the "seeing" of relief-picture material. Although the basic point, the feeling of circumscribing the object, is lost on a flat two-dimensional picture area, the active use of both hands is still necessary for reading and understanding these displays.

It is well known that the right and left halves of the brain "connect" to their antennae, the hands, from which they sift impressions received in separate and different ways. Dr. Roger W. Sperry and his associates at the California Institute of Technology determined that both hemispheres of the human brain are involved in higher functions of comprehension and

that the two hemispheres employ different methods of processing information (Edwards, 1979).

Accordingly, it would be advantageous for the blind reader to use both hands when quickly scanning a relief display. By moving his or her hands together systematically from the top to the bottom of the display—vertically, horizontally, or in circles—he or she would receive individual impressions from each hand, get an overall insight, and eliminate the chance of overlooking a part of the picture or map. With this technique in mind, you may be able to reach some conclusions about the size, simplicity, and placement of the elements in your layout.

Legibility of the symbols is of utmost importance. Because of this, it is frequently necessary to enlarge inkprint graphics. Keep in mind that younger children (and some diabetics who may have lost some sensitivity in their fingertips) seem to require larger size symbols, shapes, and textures than older children. But also remember that small children have small fingers and may lose their way on forms that are too large.

FORMAT

The size of a display's format is easier to resolve. Every country has a standard paper size, but all countries do not use the same size. Therefore, the inches and centimeters of certain paper types may be meaningless to you. (They are of little importance here, because the suggestions in this book are adaptable to the paper sizes of all countries. For further information on paper sizes, see Appendix 1.)

Several factors are decisive in choosing format size:

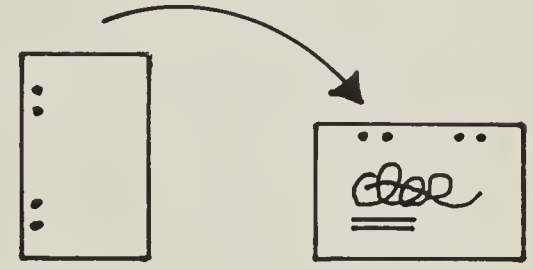
- Is this to be a one-of-a-kind or a mass-produced display? For a single-copy picture or map, the size is not governed by any outside factor such as typical paper sizes or machinery dimensions. The relief picture could take on the magnitude of a wall frieze, or it could be as small as a playing card or a pocket map. However, for a mass-produced display, the machines used in the duplicating process—vacuum-forming machine, the photocopy machine, the silk-screen frame, and so on—will dictate the maximum size of the format. The size of available paper or plastic is also of major importance.
- In which form will the material be presented? If it is to be

made for a book, the standard size of the braille book decides the maximum size of the display. If it is to be used as an unbound picture or map to augment classroom material, the format may vary. For low-relief pages to be used by a student in a braillewriter, the format is decided by the maximum width of paper or plastic that can be used in this machine.

The size of books, maps, and pictures for young students who prefer a smaller format is half of a standard braille book page. In some countries, it is referred to as A5 size. Small children find this size less bulky and easier to carry than the larger size; it takes up less space when in use.

This format is also economical. Two books can be printed at the same time, as they take up half the area of a standard braille page. Plastic for the standard braille page, already vacuum-formed and cut to standard book size, can be reused to produce this book format. If the recycling of used plastic pages is of interest from the production standpoint, the expense of making a smaller frame to be used in the vacuum-forming machine is negligible.

- How much information is to be presented on a page? If the picture or map is larger than the standard format allows — if there is too much information for a standard page or if a step-by-step technique is desired—the page format must be increased. This can be done by placing the display horizontally on a vertical page (see A and see also "The Reading-Direction Arrow" in Chapter 4).

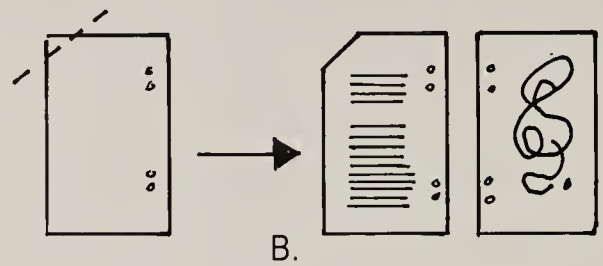


A.

It is important that the picture or map always face *away from* the binding, so that the reader will not have to reach across the binding and find that it is in the way. Also, be sure to leave enough space for a wide margin to ensure that part of the relief display or braille text does not disappear into the binding when the page is put into a binder.

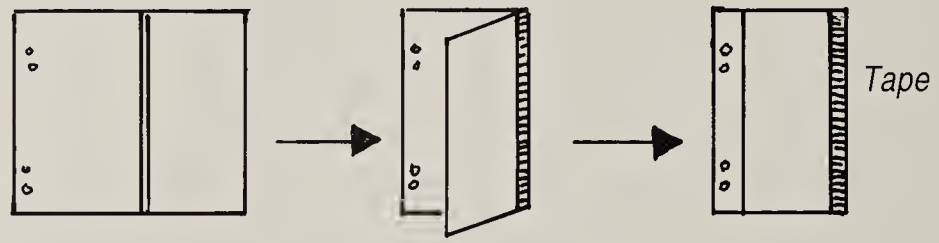
Another way to change a format is to place the display on one page and the description or key on the facing page. With this system, the student does not have to turn the page for information while scanning the display. (It should be noted, however, that individual pages are facing pages when two pages that make up the same display are bound together or placed together. Their text or graphic displays face each

other.) When the braille transcriber writes a facing page, it may be advantageous to clip off the upper left-hand corner of the page to indicate that it is to be bound backwards and ensure that the bookbinder places the page correctly (see B).



B.

For displays such as maps or step-by-step displays that need an additional key or legend, another page is often attached to the outside edge of the right-hand page (see also "Simplicity" and "Key or Legend," Chapter 4). This page should be narrower than the page to which it is attached so that it can fold into the book without being caught in the binding (see C). This allows room for a larger display. With this technique, be sure that you use some sort of system to lead the reader from one section of the display to the next: a reference line, an embossed connecting line, text, numbers, or arrows.

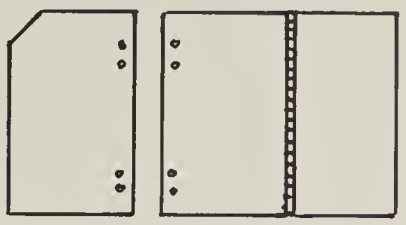


C.

Put the pages together with a very flexible tape that will not dry out and become brittle; 3M medical tape, Micropore 1535, in widths of .4 in. and 1 in. (10 mm and 25 mm) has been well tested (see Appendix 3 for the address of the 3M Company). Leave a small space between the two pages when you tape them together to allow them to fold more easily. To prevent the tape from becoming sticky between the two sheets, sprinkle it lightly with ground chalk.

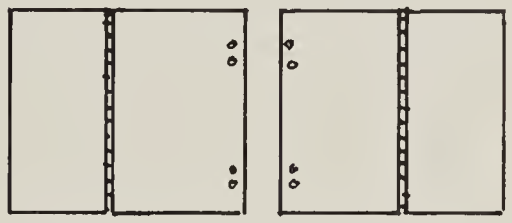
This type of format is excellent when there is too much information or the information is too complicated to be presented on one page, yet there is a need to keep the information together, such as with maps and their keys, electrical-connection programs, and integral parts of a complete figure. It is also a more expensive process, which calls for the special attention of the producer and the bookbinder.

The foldout page and the facing page can be used together for a maximum display area. As shown in illustrations D and E below, foldout—facing-page combination D, in which one foldout page is used, is preferable to combination E, in which two foldout pages are used. This is because E requires quite a bit of table space to read when it is extended to the fullest. The amount of level space needed to read a standard braille book is approximately 2 feet (60 cm), which does not include any foldout pages.



D.

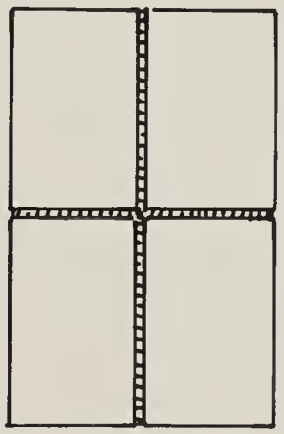
Large-format maps and diagrams are made by putting together several display sections, vacuum-formed from several masters (see F). This technique may be necessary for items such as world maps or street maps. Attach the sections with flexible tape that can withstand a lot of folding.

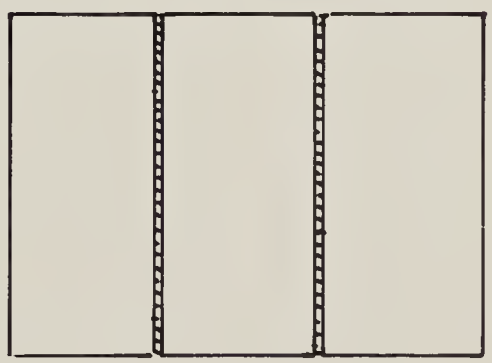


E.

The following factors also influence the final appearance of the book or display:

- The elevation of relief material that will be bound in a book should be comparatively low—approximately .04-.08 in. (1-2 mm).
- To facilitate the scanning of tangible graphic displays with both hands, a book, page, or single display should lie flat on a firm surface. Displays are best understood when they can be examined without the distracting bumps from succeeding displays poking up underneath the page that the reader is studying.
- A spiral-bound book will allow the student to fold back all pages but the one that is to be studied, irrespective of the location of that page in the book. A loose-leaf binder will permit the student to remove the page and examine it freely in any desired position. The same is true of unbound display material. The advantage of a loose-leaf binder over permanent binding is the facility with which displays can be read, replaced, and repaired.





F.

USE AND READERSHIP

Some types of tangible graphics fill an important need. Yet it is difficult to define time limits or price tags for them. Will this material or book be used for one year or for several years? Will it be used by many readers or by few readers? Answers to

these questions will determine the time and expense that are necessary to make the display.

A tactile-experience picture or map is in a category by itself. It is often a separate display that is produced so that the reader can experience different materials. As a book illustration, it stimulates young children's sense of touch and encourages recognition.

Tactile-experience maps are extremely valuable to beginning map readers. The natural materials are easier to discern, understand, and follow than their plastic counterparts. But tactile-experience displays may be more expensive and time-consuming to make. Therefore, your decisions about what to produce and how to proceed should be based on the teaching value of the final material. A display made under primitive circumstances, with textures obtained from the surrounding countryside or from packaging available at the local store, may be more meaningful to a blind reader than pictures or maps that are constructed in studios where all sorts of conceivable materials are available. It is the imagination and knowledge put into the display that will reap results if the display is well thought out, and such a display may be used by many readers for many years.

Basically, this chapter has been concerned with displays for textbooks. A mass-produced book that is used for several years, such as a book on medicine, anatomy, or biology, will serve a number of students and therefore deserves the investment of time and money.

An illustrated loose-leaf supplement could be produced that could augment study material in other textbooks. The relief material could be added or removed each year to update the supplement and thus extend the use of the display and justify the expense and time involved.

A textbook that requires a new edition each year or one that is read by only a few students may have to be produced in a more austere form. Use simple embossed-line drawings or displays made on microcapsule paper. If possible, reuse masters of displays previously produced. It may be necessary to limit the amount of relief material in such a book.

The number of pictures, maps, or graphs in a book is governed by the amount of information that needs to be illustrated—can it be described by words instead of by tan-

gible graphic displays? Judge each picture harshly before making it.

The demand for tactile graphics in textbooks for blind and visually impaired students is increasing. To keep up with the needs of these students, who are in integrated programs and schools throughout a country—each one attending a similar course and each one using a different set of textbooks, written by different authors—is a frustrating endeavor. There is hardly a production center today that has the personnel or the funds to produce material that will please everyone. Consequently, a producer has to be selective and decide which material should be made into tangible graphics and how it should be produced. What the priority is depends on demand, importance, time limit, and economics. Perhaps some of these problems are out of your hands, but it is important to be aware of their existence. They influence how you will work, the time and effort spent on your product, and its price.

The following description by Levi and Amick (1982, p. 421) sums up the key considerations:

> When presented with a good tactile drawing, the blind person should be able to locate the important information by quickly scanning the page with the hand. The important lines must attract attention immediately by being rough or highly embossed. The size must be adequate for individual lines to be traced, and the labels must be placed so that they do not detract from the figure itself. Important parts of the drawing must stand out, and the page must not blend into an undefined, overall texture of lines and braille. In short, it must not seem cluttered or undifferentiated.

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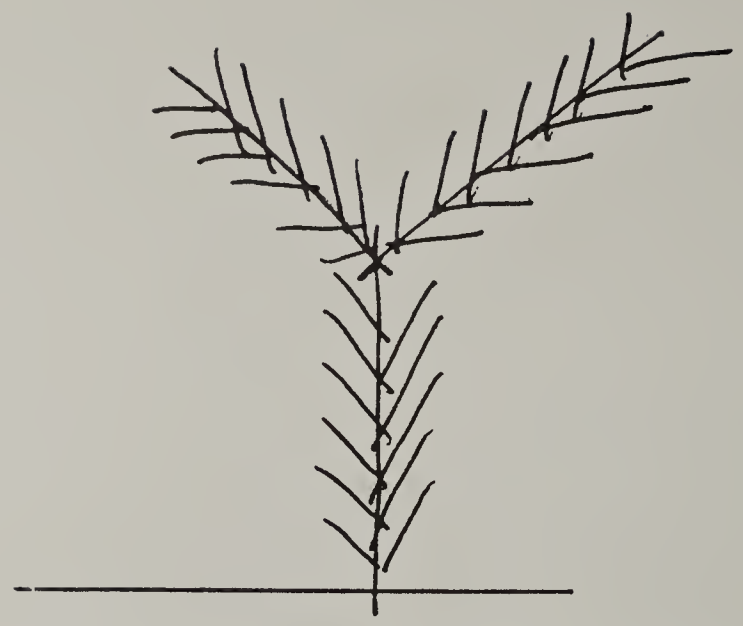
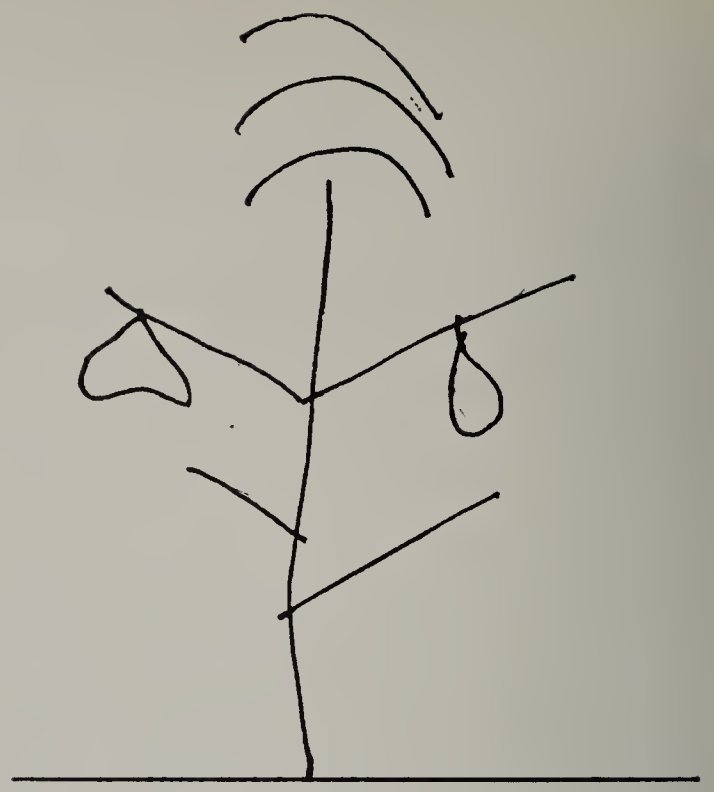
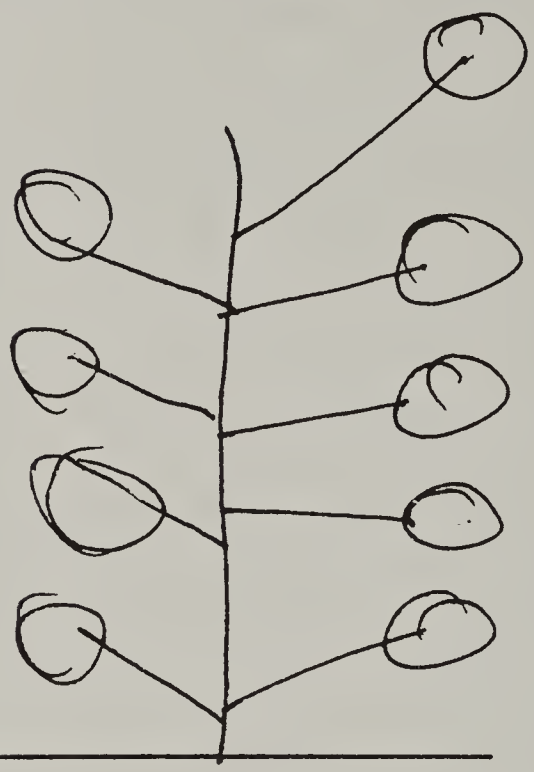
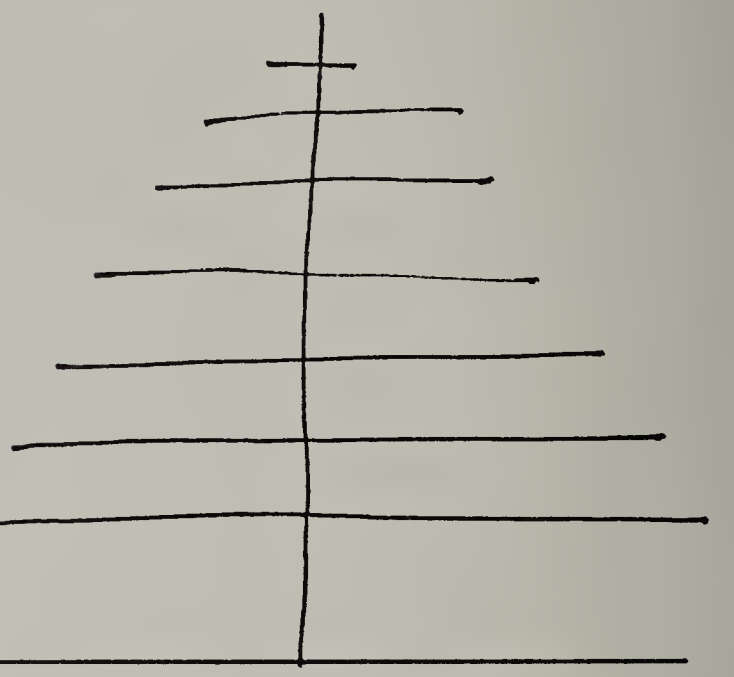
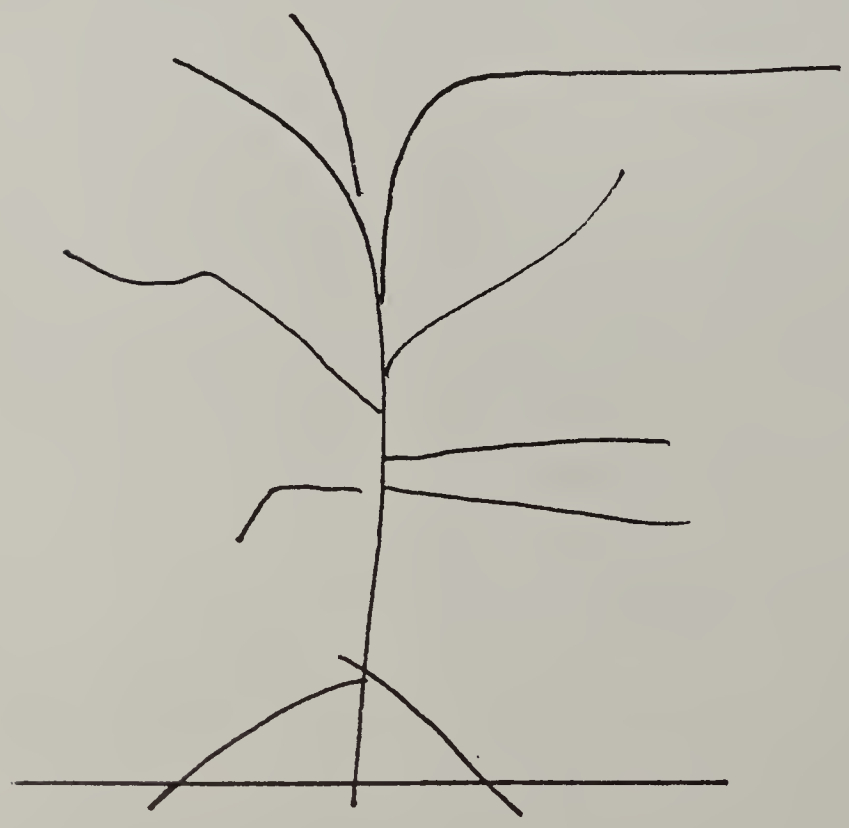
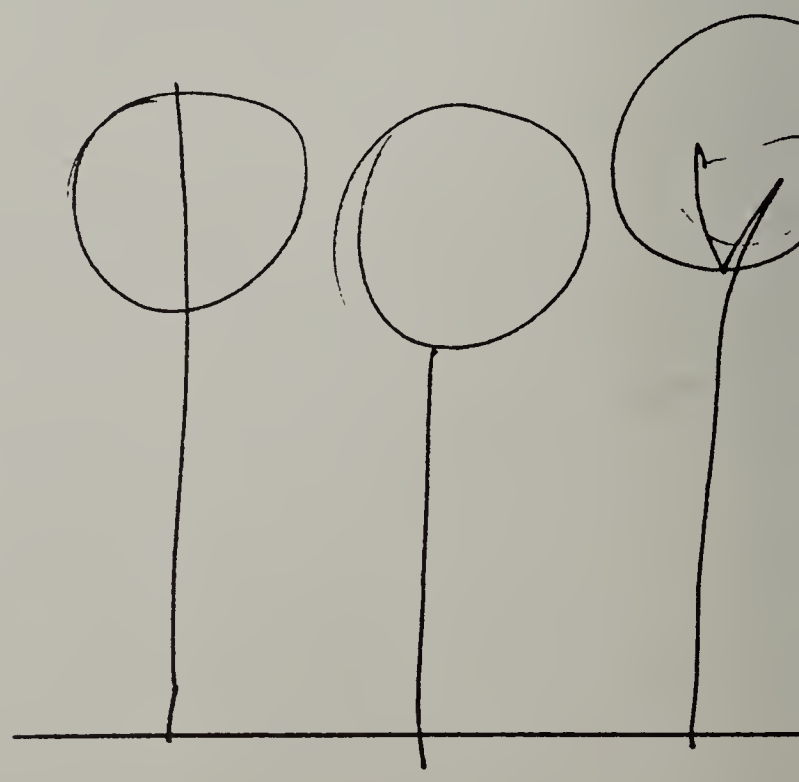












CHAPTER 4

Pictures

Too many lines in a tactile graphic display cause confusion. Keep your pictures simple. Decide the purpose of the display and portray only the most important element or elements—preferably, only one or two figures or objects in a picture.

SIMPLICITY

Do not use unnecessary detail. Each object, form, or symbol must give the reader vital information and be easy to distinguish. The forms should therefore be kept simple and without ornate decoration, and their outlines (silhouettes) understandable. The problem of too much information in one display can be alleviated by breaking down the display into a step-by-step series of pictures.

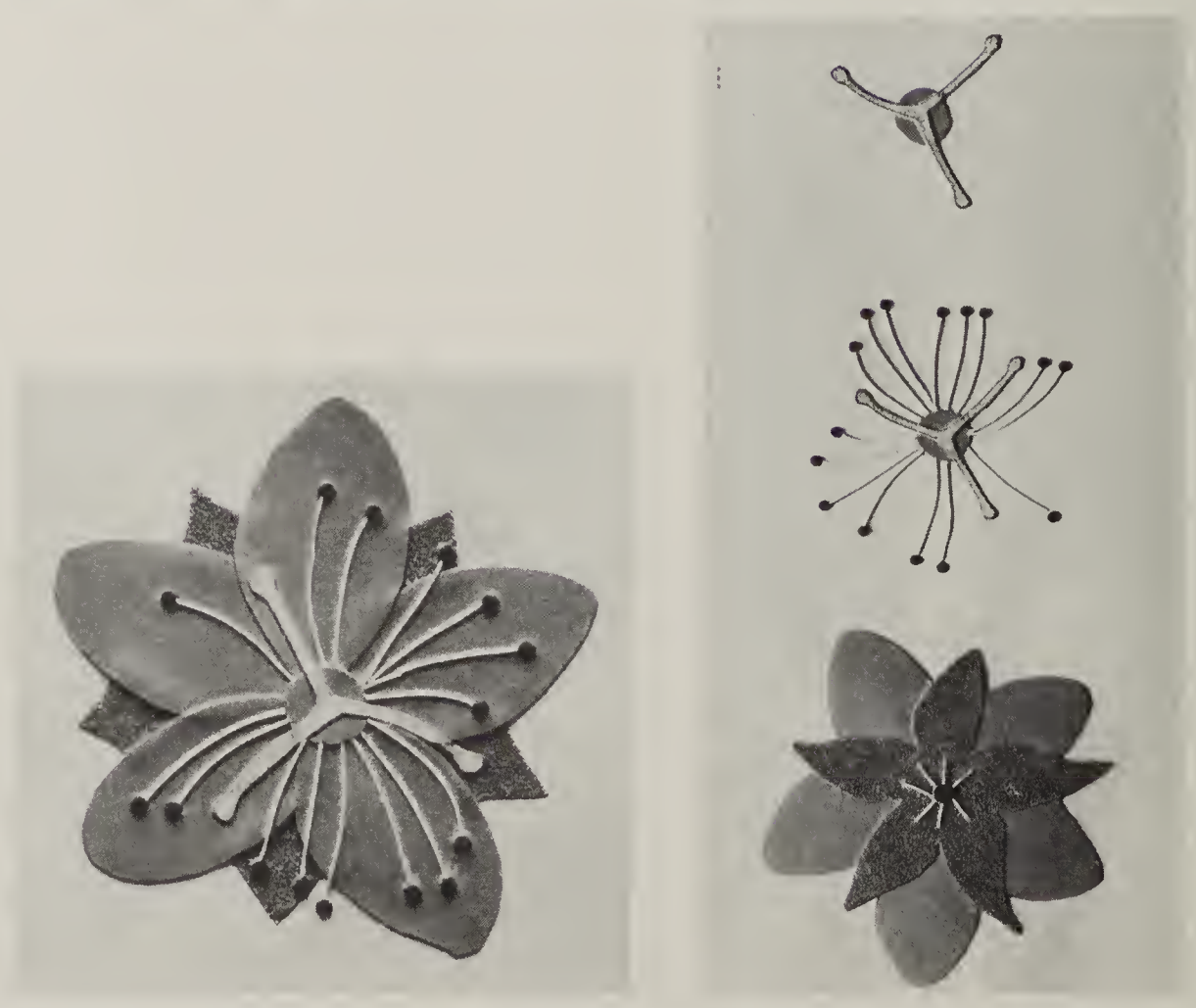
OPPOSITE PAGE: Trees that children ages 6 to 9 who are blind from birth have drawn. The straight baselines have been added. These trees are taken from different drawings from several countries.

Step-by-Step Displays

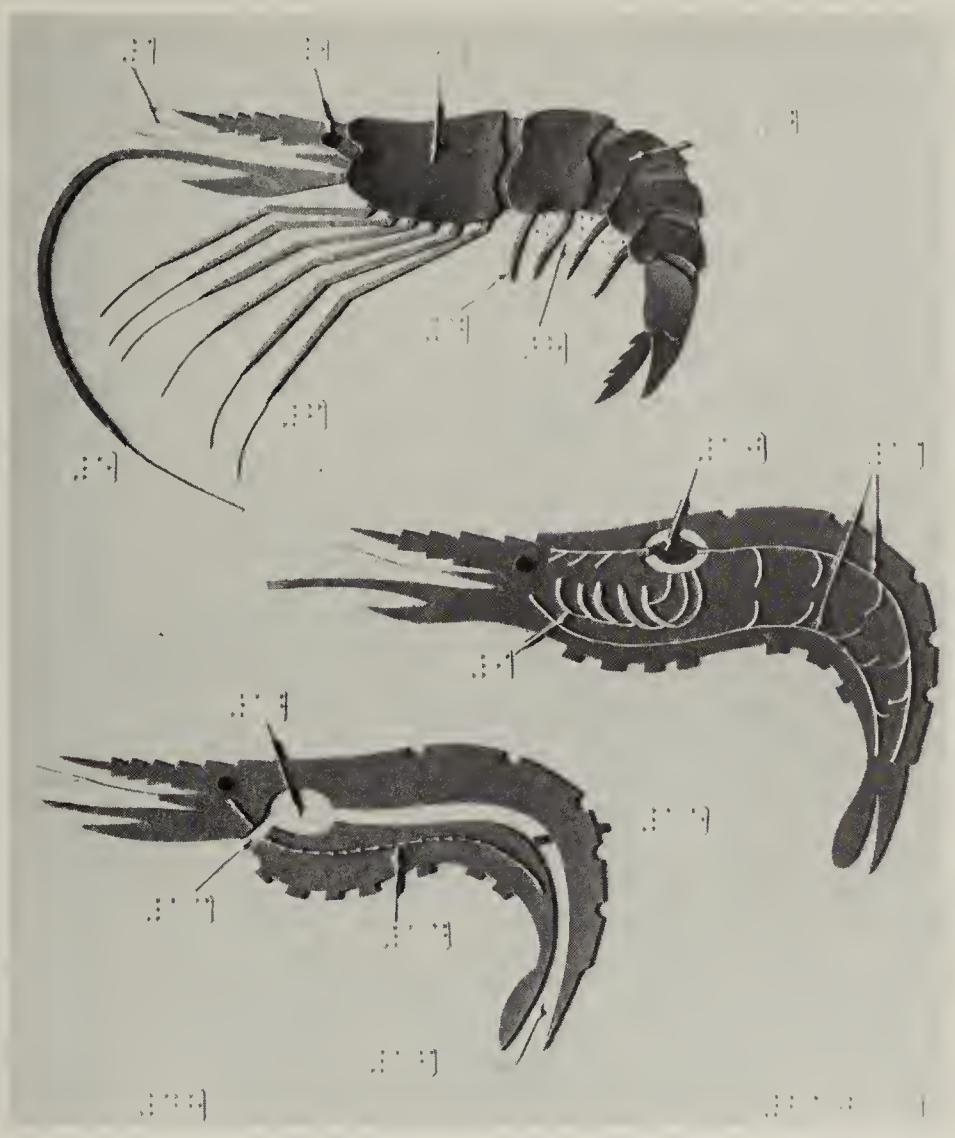
Following are the four methods used to produce step-by-step displays:

1. In this method, the scale of the different diagrams is kept constant. First, portray the basic form of the figure or object. Next, show the various components of the figure or object, either by showing several different components separately or by adding new information to each progressive step until the final figure or object is complete. This method may necessitate three or more diagrams or parts of diagrams (see A and B on the following page).

A. The first picture is a textbook illustration of a soybean plant. The second shows the plant divided into three parts in a paper-on-paper buildup.



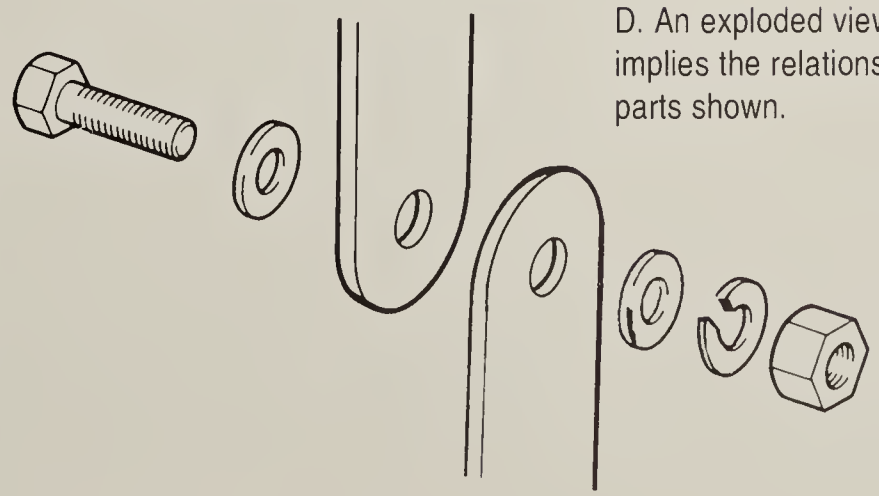
B. A flower shown in a step-by-step technique, method 1. This is a paper-on-paper buildup with string added to the display.



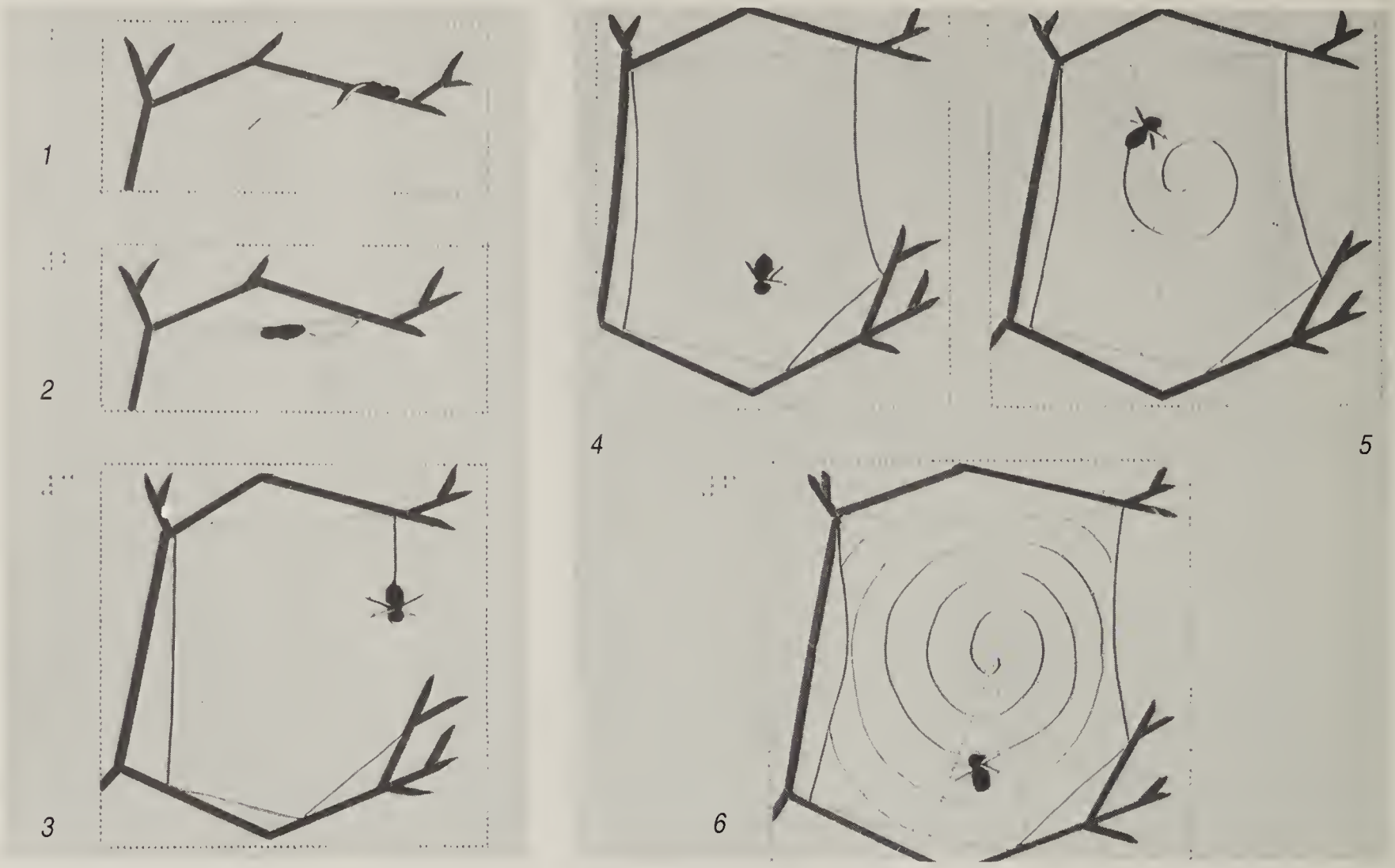
C. The basic form of the object is repeated in each element in this display.

Note that to simplify figure recognition, you can repeat the basic form of the figure or object in each element in the display (see C). The components can be shown within the boundaries of an embossed line drawing or mounted on top of a simple relief background shape of the figure or object. It is important to keep the scale and size of these basic forms the same.

An exploded view is another type of a step-by-step display. This is a drawing of an object showing its component parts separately, yet the parts are arranged in such an order that the reader will understand the relationship of these individual parts to each other and to the object as a whole (see D). This technique is often encountered in engineering and technical books. The relief display based on an exploded view should not be drawn in perspective. It should be made as an overhead or as a frontal view.



D. An exploded view that clearly implies the relationship among the parts shown.



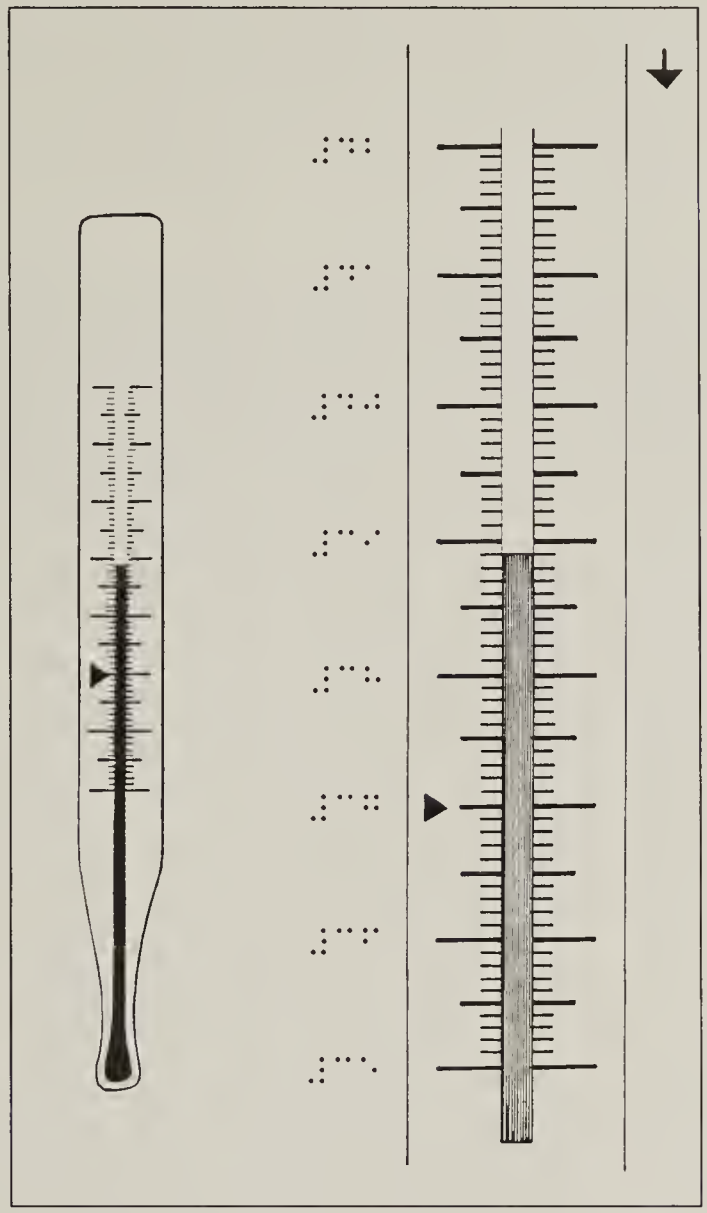
Building a spider web, using method 2.

2. In this method, the scale of the different diagrams is kept constant even though the physical position of the figure or object may change within the display. First, portray the basic form of the figure or object. Next, portray the different steps of growth, decay, changes of character, changes of position, and so on that the original form may go through (see above). For example, a plant, figure, or animal grows larger in each step, but the overall scale is not altered.
3. In this method, certain details of the display need to be enlarged in size for reader comprehension. Some displays contain a single, small area of importance that should be enlarged (see the following page). Make the figure in the overall display complete in all areas except the area to be enlarged. This area can be simplified, since it will also be treated in the separate display. Indicate the area to be enlarged by enclosing it in an embossed circle, square, or rectangle, which is made either with a very fine dotted line or by giving the area a special texture.

   To eliminate confusion, the textures, elevation of lines and symbols, and the general layout of the enlarged area should be similar to the corresponding area marked on the overall

display. Place the enlarged area on the same page, a facing page, or a foldout page, depending on the amount of space available within the display. It is necessary to inform the reader about this enlargement in the text of the book, in a picture description, or in the key to the illustration.

4. This method is for displays containing several areas of importance that need enlarging (see next page). First, simplify the original display by using an outline technique such as an embossed line drawing or a raised background form of the figure or object. Indicate the areas to be enlarged within the display by a symbol, figure, number, texture, or encircled area. By marking the areas to be enlarged on the original figure, you will be showing the relationship of the various areas to each other and to the figure as a whole. Next, place the enlarged area displays in logical order on the same page, a facing page, a foldout page, or pages that follow the original display. Be sure to inform the reader about the enlargement in a description in the text or in a key to the illustration.

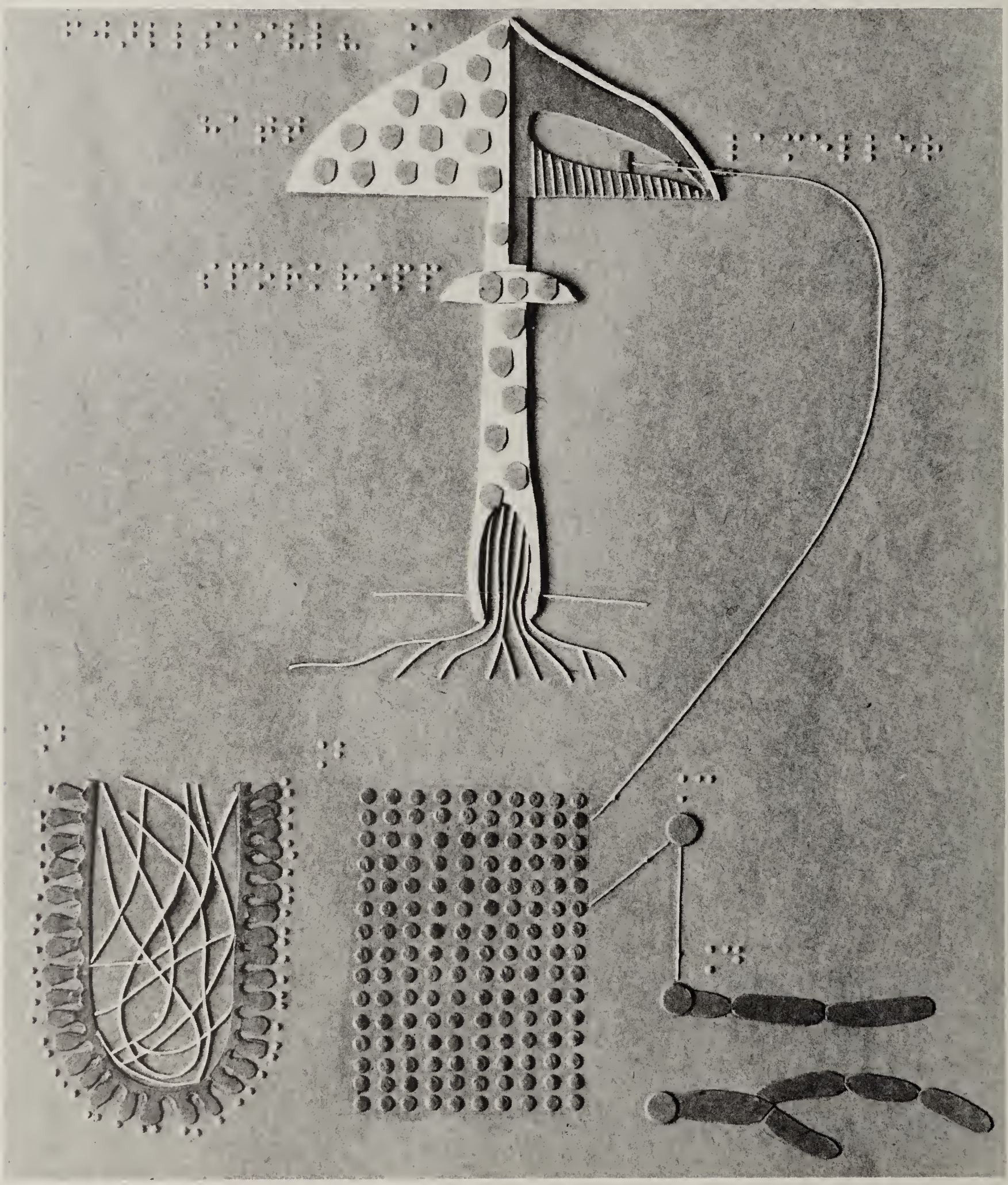


In this example of method 3, the thermometer is shown both as a complete form and as an enlargement of the temperature scale. The enlargement enables the reader to count the degrees and tell the temperature. (This is a microcapsule display.)

The step-by-step diagram system has been widely tested. However, opinions vary concerning the sequence of the diagrams. Some readers prefer building up the diagram from simple components to a final complex display, while others prefer the first diagram to be the complex display, followed by a buildup from simple components (not to be confused with a build-down from complex to a simple form). The second prefer-

In this example of the step-by-step technique, methods 3 and 4, a string is used to connect the enlarged area of the mushroom with the object.

ence is held by blind students integrated into sighted classes, apparently because the complicated version is the one in the inkprint textbook. The breakdown of this version is the blind students' key to the original diagram. In general, it may be



difficult for young readers to grasp the complete picture from a series of diagrams, step by step. However, older students have no problem with this technique if it is well done.

Some people feel that step-by-step displays take up too much room in a braille book and are time-consuming and uneconomical. However, these displays present the necessary information in an understandable fashion, and to me, that is the whole purpose of tangible graphic displays: to give the sight-impaired reader as much information as possible in the easiest possible way.

Lack of Simplicity

Unfortunately, the person who edited the picture from a first-grade mathematics book shown here was strongly influenced by the printed version and forgot the paramount question one should ask when analyzing material to be reproduced in a tangible graphic display: What is important here? Should this

Illustration from a first-grade mathematics book , *Matematik A, Grundbok* (Rosenberg, Lindström, Natt Och Dag, & Högberg, 1979).

illustration be described orally (by the teacher), verbally (in the written text of the book), or graphically?

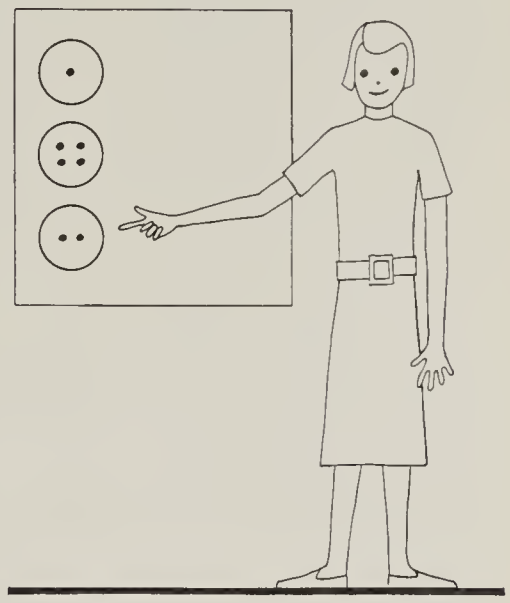
The purpose of the tangible graphic display based on the original picture and shown here is to illustrate numbers. The

This relief picture, made in the paper buildup technique, was done for the first-grade mathematics book *Matematik A, Grundbok.*

teacher is pointing to a circle containing number 4. Numbers 1 and 2 are also on the blackboard. Actually, the illustration is unnecessary. Its producer should have analyzed the printed picture more closely and seen that its only purpose was to illustrate number groups from 1 to 6. The picture and the number groups could have been explained easily in the braille textbook. However, there is a lot to learn from the mistakes in this picture:

- There is too much in the display; it is cluttered and therefore confusing to the reader.
- The boy and table do not add information to the display.
- The boy and table appear as one figure, not two separate entities.
- The table is shown in perspective and has only three legs. The reader would have difficulty understanding it even if it were a single figure.

- The boy has no legs.
- The stick in the teacher's hand is bigger than the teacher. Such incorrect size relationships are confusing.
- The pictures across the top of the display could have been made in a separate display, showing numbers 1 to 6 with geometric figures or dots.



One possible solution, but by no means the best.

Some suggestions to avoid these problems are:

- Use a page of circles containing different numbers of dots or a page of geometric shapes containing several groups of shapes. The number of shapes in each group would vary from 1 to 6. A page of braille cells, using all 6 dots, could also be used in individual groups of 1 to 6 cells.
- If it is felt that a figure is necessary here, then use a simple figure of a teacher pointing to a blackboard where three groups of dots are contained in three circles. This approach should be used *only* if the display is to be read by the blind student in an integrated class in which the teacher is liable to discuss the textbook picture with the class. It is doubtful that a blind child could understand such a display without help. This illustration is *not* the best solution to the problem. A better choice would be to show the dots without the teacher.

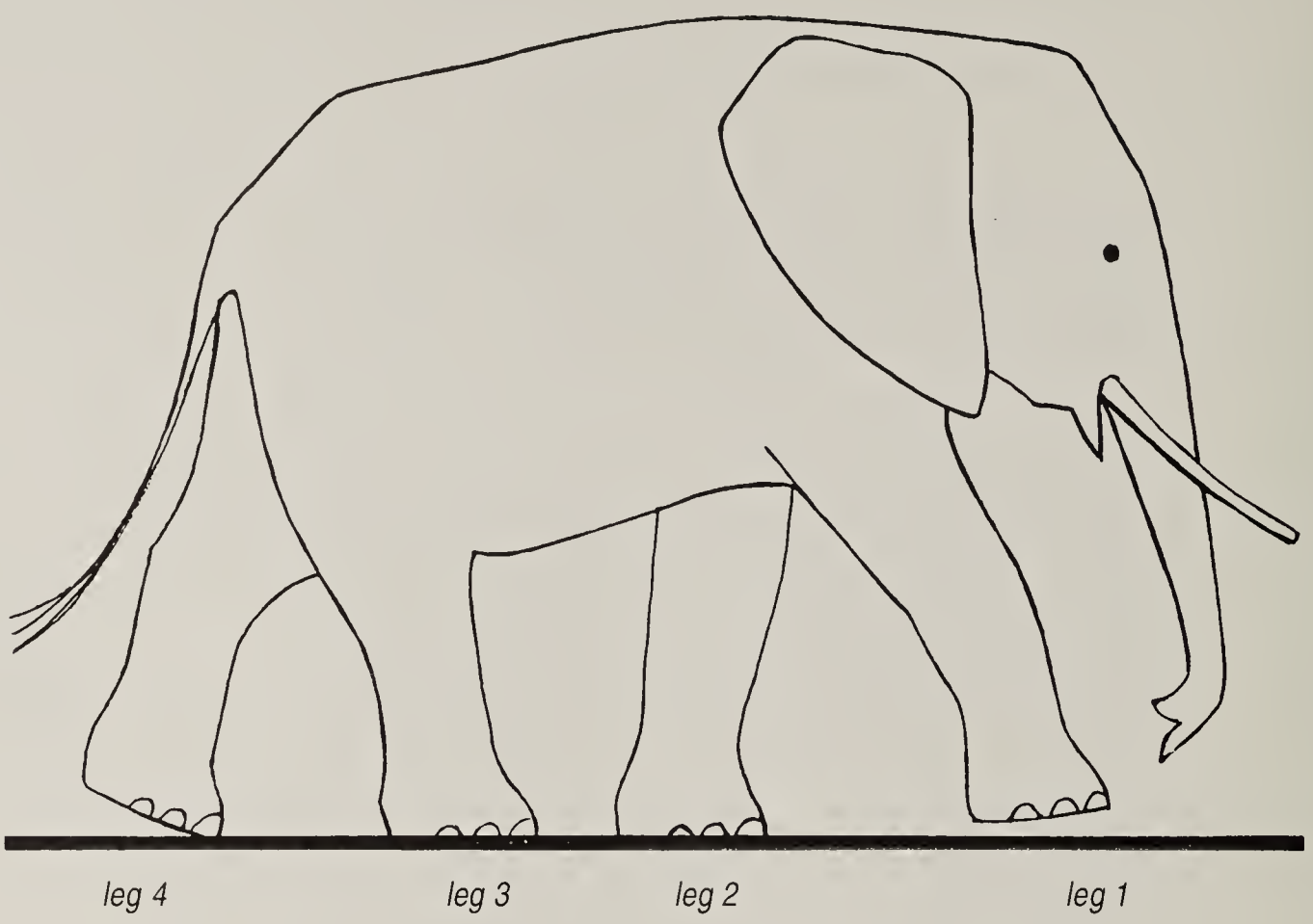
DETAILS

A cluttered diagram is one with too much detail in too small an area. If detail *is* necessary, enlarge the picture so that the different textures, symbols, lines, and so on do not make the picture too confusing. Details of a similar nature (or feel) should not be placed beside one another because they will blend together. Contrast in texture and height are most important for reader comprehension.

Basic Principles

Keep to the basic form of the object, animal, or human being. Try to stress the most characteristic element in the figure. The trunk and the tail of an elephant, for example, are very different. Overemphasize if necessary, but do not use a cartoon technique of huge heads, small bodies, or tremendous ears. The basic form, without too many details, should give the feeling of the object without distortion.

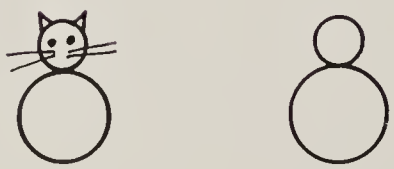
This simple form of an elephant is best understood by the young reader, since it is built up in layers of cardboard. Layer 1, closest to the background material, consists of the entire elephant. Layer 2 is the entire elephant minus legs 2 and 4, plus the toes on legs 2 and 4. Layer 3 is the ear, tusk (the end slipped under the lip of layer 2), toes on legs 1 and 2, and an eye. The elephant should walk on a line, perhaps a thin strip of sandpaper. For a raised-line drawing of this elephant, add texture to the entire animal so that the basic form can be felt.



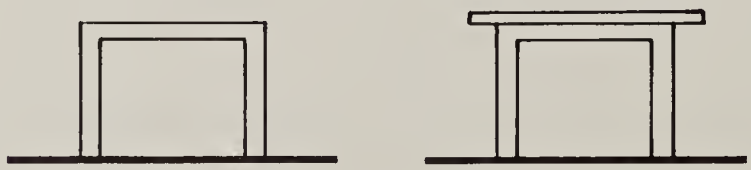
Additional Suggestions

Here are other suggestions for dealing with details:

- Make characteristic details noticeable. For example, a sitting cat without whiskers and ears could be confused with a snowman. Both have the same round forms (see A and B). Stress the important details. Another example is a table, which, if made in one elevation, could just as well be a doorway. Add an extra layer of material for the table top (see C and D). But remember, creating many irrelevant details is not only confusing to the reader, it is time-consuming to the producer. And it may make the display less instead of more informative.

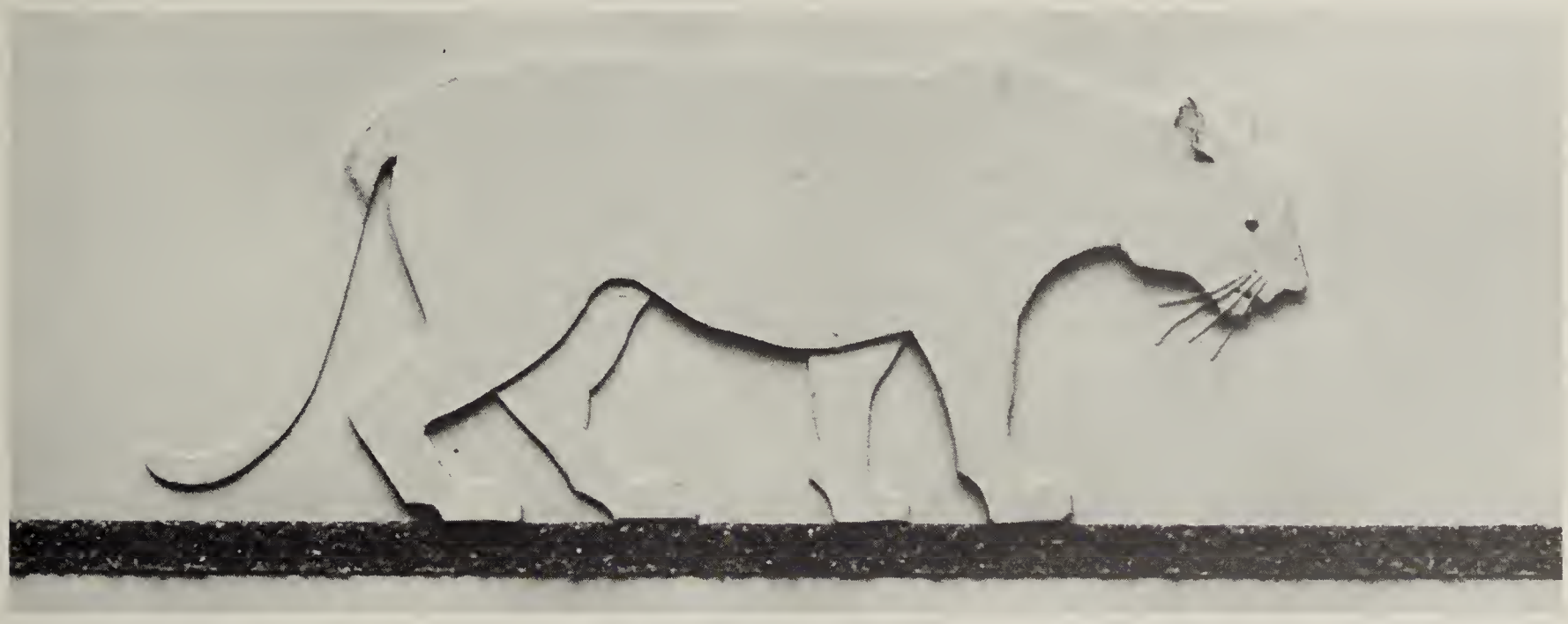


A. B.

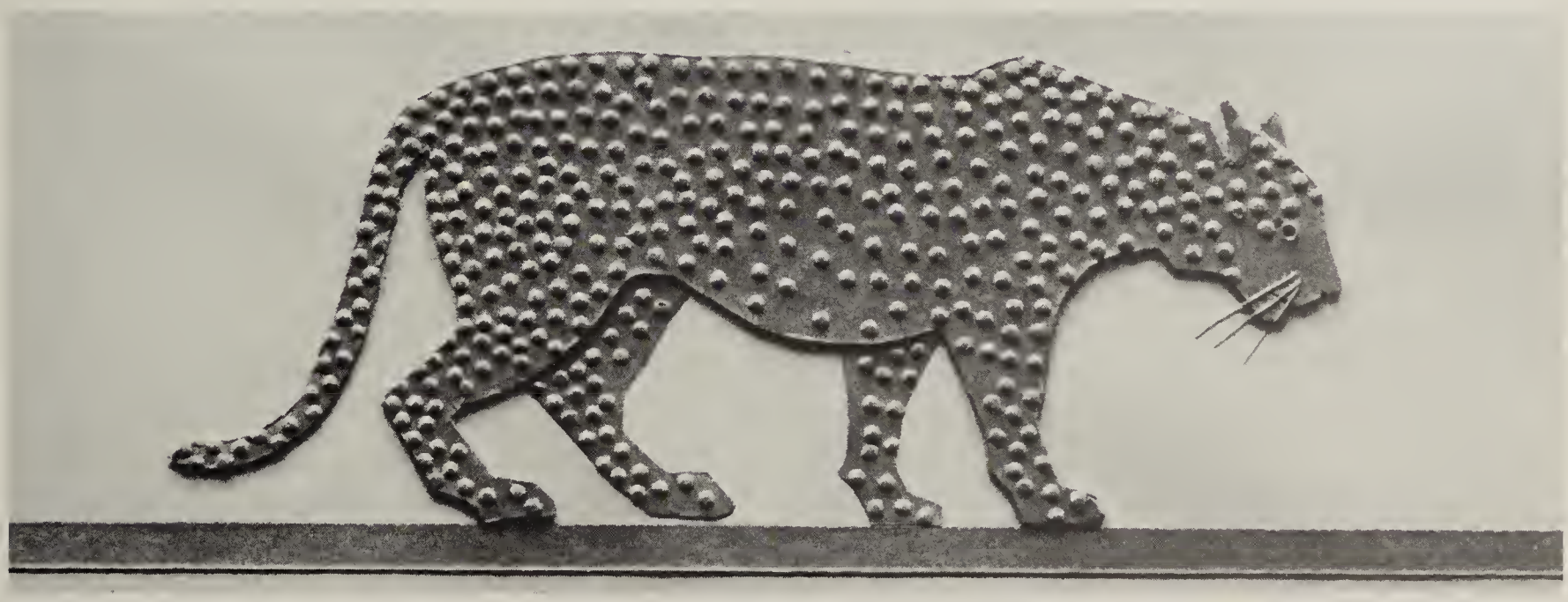


C. D.

- Some details are purely visual—the spots on a leopard, the freckles on a child's face, the stripes on an insect, or the patterns on a butterfly's wings. It may be necessary to show the figure with *and* without its visual details (see E and F). Children are curious. Show them, but also give them a verbal or braille description.



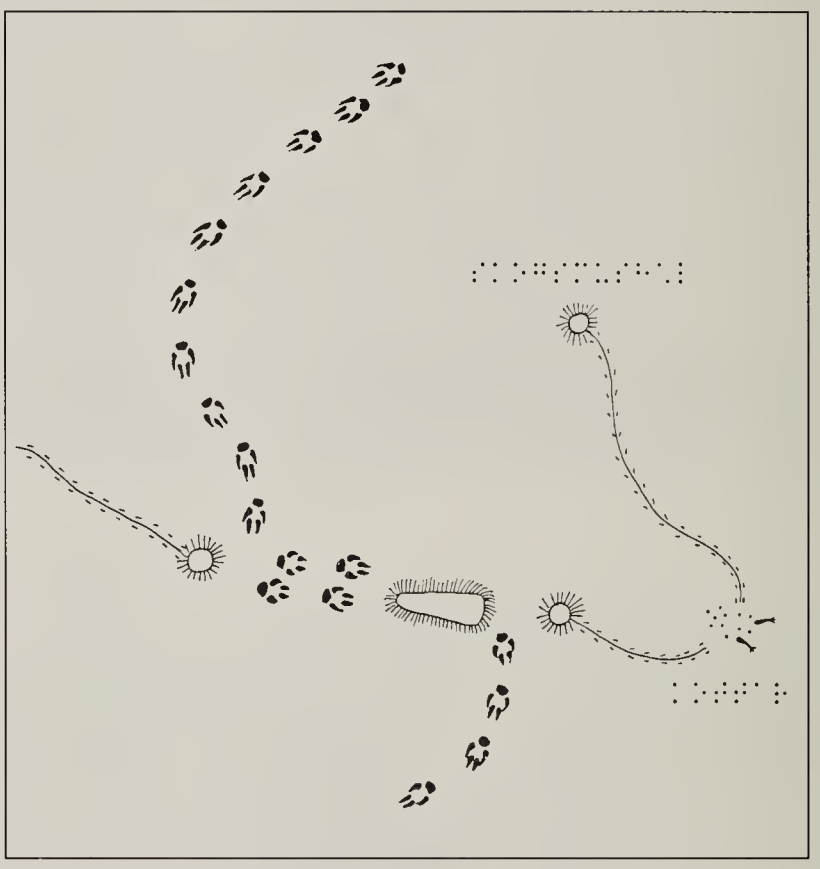
E.



F.

- If details are graphically unnecessary in a display but are necessary to the story that is being illustrated, substitute these details with letters or numbers that are explained in the key. This solution can only be used if the reader can understand braille or large-relief text.

For the picture shown here, whose accompanying text asked readers "What Happened?" (see G) the problem was to make a relief picture that was simple enough for a blind reader to understand but that did not give away the answer. The picture illustrates various points relating to details and simplicity. In this scene of winter woods are the tracks of a mouse and of a larger animal, three mouse holes, the exit from the mouse's nest, the escape hole made by the mouse when it sights the large animal, and another hole that the mouse makes when it safely emerges beyond reach. The third hole is made by the



LEFT: G. Picture whose companion text asked, "What Happened?"
RIGHT: H. Relief display for the picture, "What Happened?"

larger animal scratching in vain, looking for the mouse. The most important element is the tracks. The woods are immaterial, and the word "woods" written on the display or described in the text of the book could be substituted for them. Many trees would clutter the display and bewilder the reader.

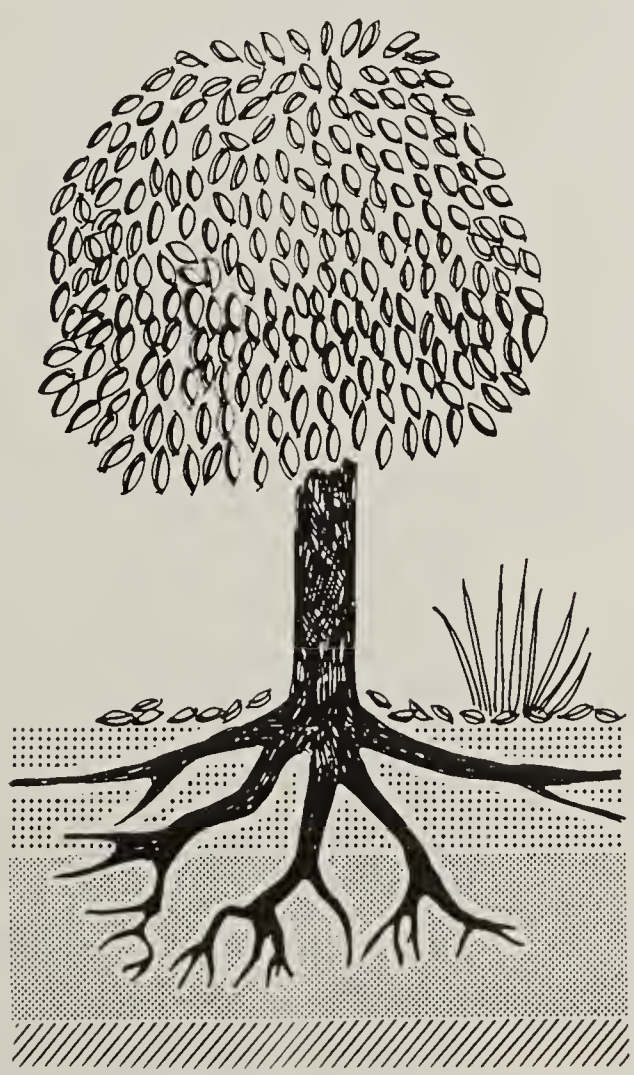
It was necessary to make many copies of the relief display based on this illustration (see H), since it was included in a popular textbook. The production method was microcapsule paper. Simplicity is paramount when using this method of mass production, since the relief is only one level above the paper surface.

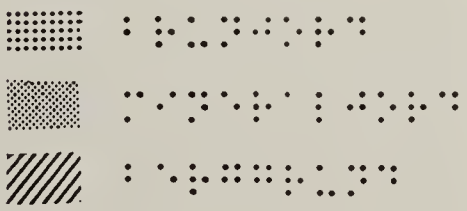
Holes shown as filled-in black areas are unusable. In the original making of this relief display, the black area swelled up when the microcapsule paper was heated in the infrared

heater and became a relief form itself. In contrast, holes represented as enclosed areas with lines radiating from the outline (see H) allowed the edges to swell and formed a very understandable indentation. As a result of this solution, children have enjoyed the page and have written some amusing stories about the mouse's adventure.

THE COMPLETE OBJECT

Try to portray objects, animals, or humans in their entirety—do not show half of a dog or three-quarters of a car. It is easier for a person to understand a picture when he or she can relate to a complete form. In the case of the textbook illustration shown here, the tree with its top cut off might feel rather strange to the blind reader. In contrast, the full tree form shown in the paper relief picture leaves no doubt as to what the picture portrays.





A textbook illustration in which part of the tree shown is missing, along with the drawing done for a microcapsule-paper relief picture.

One exception is when there is a row of figures, animals, or objects going across a page from one edge to the opposite edge. I once made a page with a row of horses galloping across it. Only the back half of the first horse was shown and only the front half of the last horse was visible. When tested, blind and sighted children alike turned the page and examined the back to see if the remaining halves of the horses were there. They did not feel that the half-horses were some strange new creatures; they were simply curious to find out where the rest of the animals had gone. I explained to them that the line of horses was too long to fit on the page, and the children accepted this explanation. However, it is better to include a verbal or braille description whenever a new idea is presented or things are done in a different way.

Blind children have told me that they prefer to feel both arms and both legs of a human being and all four legs of an animal. Naturally, there are exceptions. The first principle to remember is to keep the action simple and understandable, and if a human figure is shown in profile with an object in his or

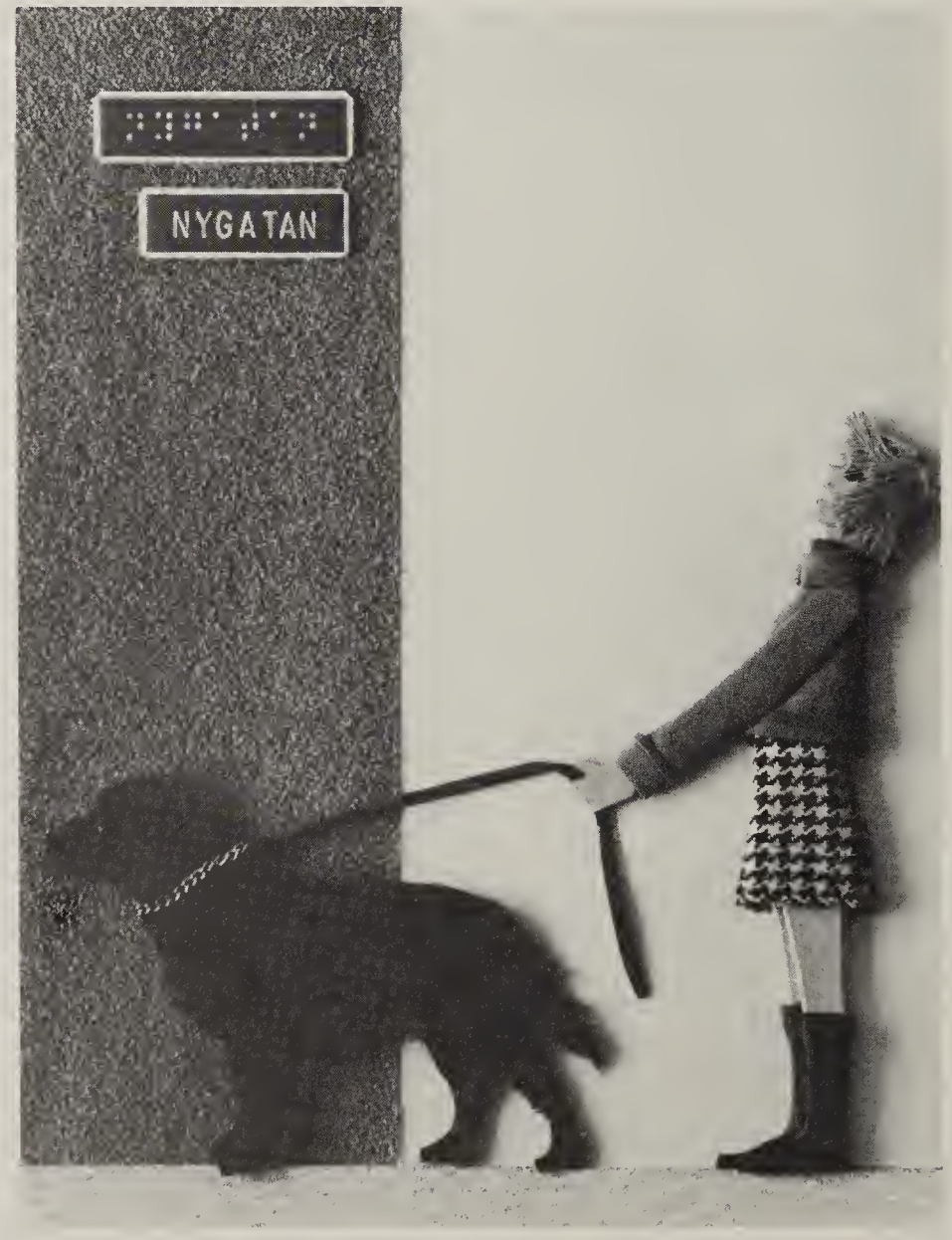


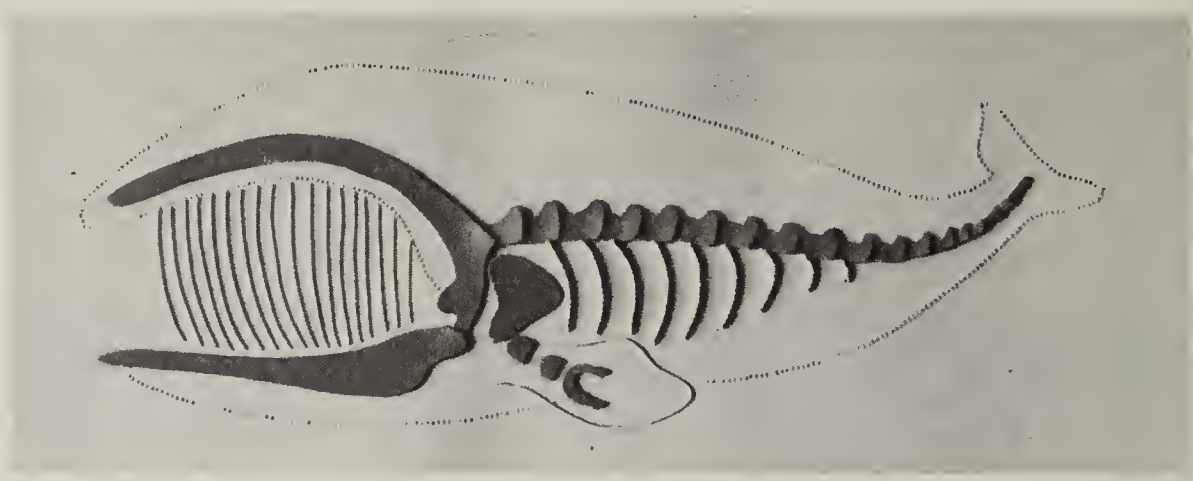
Illustration of a girl and a dog in profile, from *Red, Green and Blue Men*, a book about the police department and its work (Edman, 1977).

her hand, and the addition of a second hand and arm would crowd the area, you should leave them out. In the illustration of the girl and the dog shown in profile on the previous page, the addition of the girl's second arm bothered children because it seemed to clutter the picture, and it was therefore removed.

In this display, the shape of the ear is on a solid form.

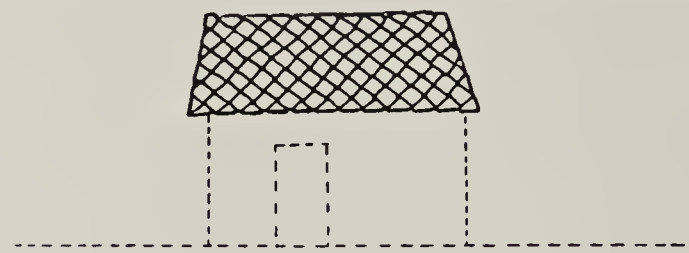
Part of an object, pictured out of its natural surroundings or context, is difficult for a young reader to understand. A human ear, pictured by itself, could just as well be a shell. However, if it is portrayed in the right place on the head, there is no doubt that it is an ear.

Part of an object can be mounted on the background material within an outline form of the object as a whole. This outline could be made with a spur wheel or formed by string, wire, or a thin cardboard outline. Or the object could be mounted on a flat undetailed form that is cut to represent the basic shape of the entire object. The pictures of the ear above and of the whale on the next page are examples of these techniques.



The outline of the whale is done in embossed form in this display.

The same technique can also be used to give special emphasis to a particular part of an object, such as the roof of a house, as shown here. The roof could be made in relief, while the house could be indicated by an embossed line.



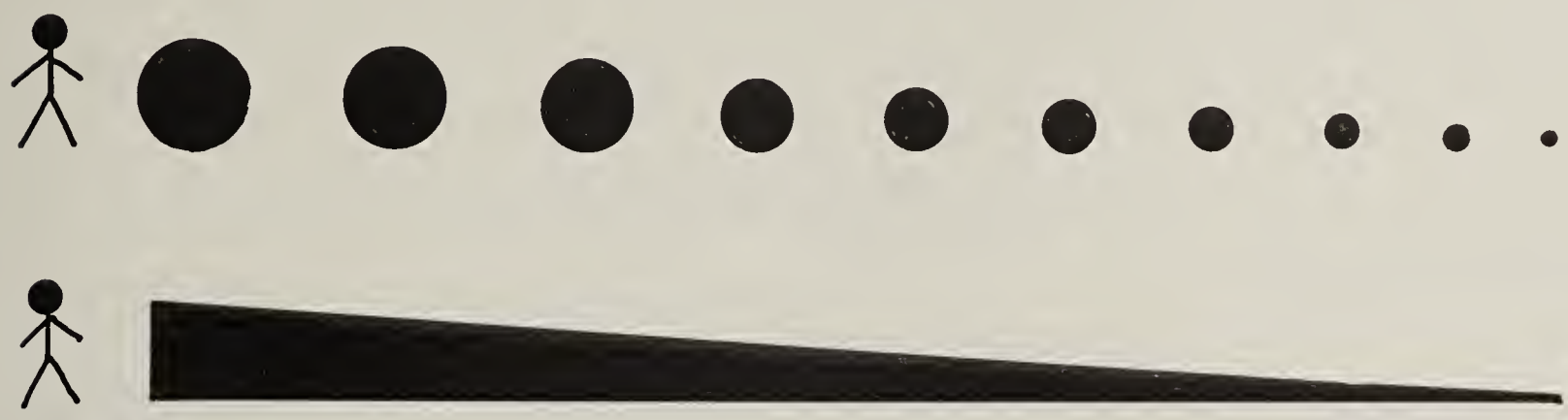
PERSPECTIVE

The word "perspective" occurs so often in our vocabulary that the process cannot be ignored even if it cannot be experienced visually. The process itself should be explained to blind and visually impaired people in both words and pictures. Out of sight may not mean out of an understanding mind, if the situation is described with both pictures and three-dimensional objects (see A and B).

A. A vertical plane or profile view of trees in perspective as explained by a person with sight.

B. A horizontal plane or overhead view of the trees in A.

Perhaps the easiest and best way to explain perspective is to compare it with sound. Sound and pictures together may give a more complete description of a visual phenomenon. The louder, larger sound is the closest one, and the fainter, smaller sound is farther away (see C). (As a general practice, however, relief material for visually impaired people should be portrayed on one plane only.)



C. A series of sounds.

Figures and animals should be portrayed in full-front view or in profile. Arms and legs should not be foreshortened and bodies should not be turned to a one-quarter or three-quarter position, since these visual characteristics make the figure seem physically deformed to the blind reader.

Human feet are easily understandable if they are placed at right angles to the legs (see D). A shoe felt from the toe end loses all feeling of being a shoe. Yet, strangely enough, toes at this angle can be easily identified (see E).

D.

E.

Buildings, houses, streets, furniture, machines, and other objects should be pictured on a vertical or horizontal plane, not at an angle. A relief display of a three-dimensional object in perspective will be a muddle of lines and textures that will probably confuse the reader. One of the problems of understanding such a diagram is that part of the figure is missing; it is hidden from sight (that is, cannot be felt) behind another part of the object. For example, a table portrayed in perspective may show only three legs.

Geometric figures can be taken apart to show each side of the figure in relation to the other parts of the figure (see "Geometry," Chapter 8). Some blind students integrated into sighted classes have requested that several of the inkprinted, three-dimensional drawings appearing in class textbooks be

repeated in their braille books, along with the nonperspective drawings of the same figure, so that they can try to follow the presentation of the figure made by the teacher to the sighted students in the class. However, as a general rule, for comprehension and clarity, avoid the direct portrayal of three-dimensional diagrams when substitutions or adaptations can be made.

POSITION

Place human beings and animals in a natural physical position. Distorted action is difficult to understand unless it is explained by an accompanying verbal or brailled description.

The relief display of children playing with blocks that is shown below is a good example of a bad picture. The position

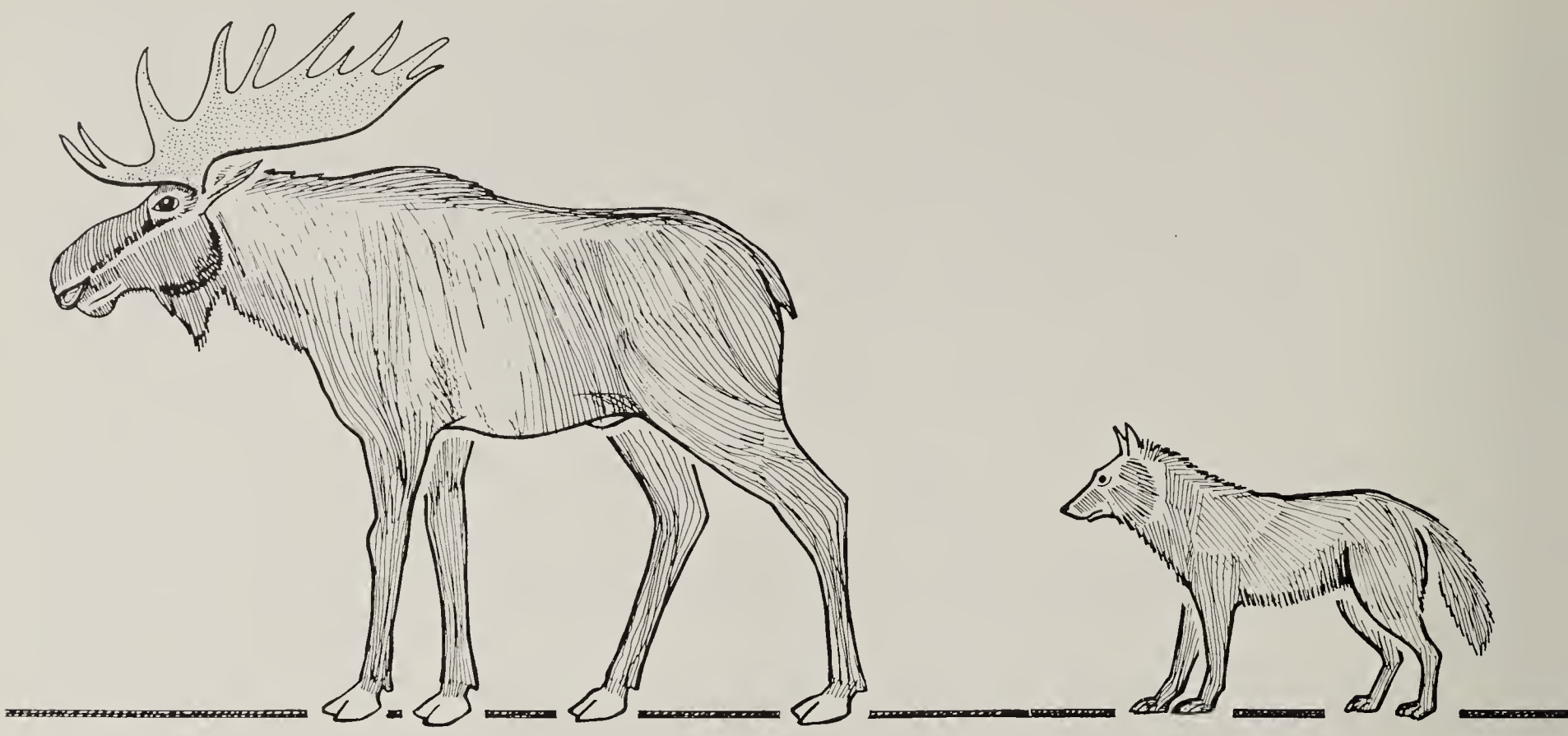
Relief display of children playing with blocks.

of the children is difficult to understand. They are supposedly sitting on the floor playing with building blocks, but one appears to be dancing, and the other seems to be falling backwards. In addition, figures are free-floating; there is no reference point to which the reader can relate the objects. No reason is given for the peculiar position of these figures. Had the figures been placed in a position like the one shown below, with the floor (reference line) indicated, the display would have been easier for the reader to understand.

This illustration appeared in the first-grade mathematics book *Matematik A, Grundbok* (Rosenberg, Lindström, Natt Och Dag, & Högberg, 1979). The relief display shown on the preceding page of children playing with blocks is one-half of this original picture.

REFERENCE LINES

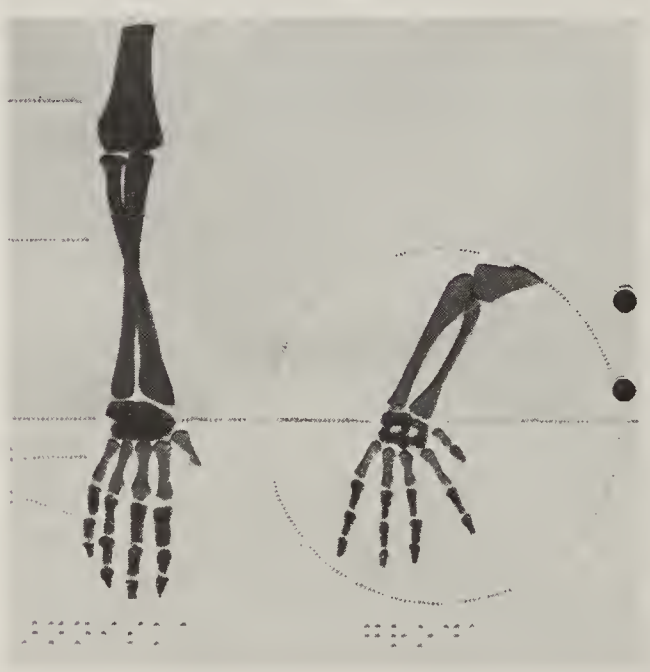
Figures, animals, houses, cars, furniture, flowers, and mountains should be placed along a line in a display to keep the objects from becoming free-floating forms and give the reader a point



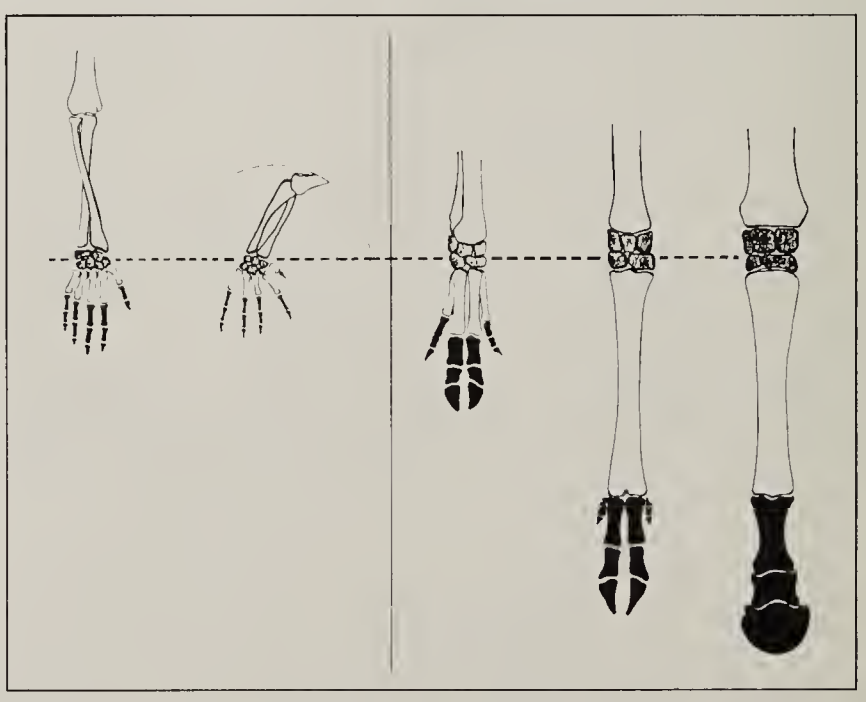
Microcapsule display showing the relationship of the elk to the wolf, the fox, the lynx, and the badger. These three panels of a foldout display are held together by the reference line. The line also enables the reader to establish the size relationship among the animals.

of departure—a reference—to which he or she can relate. If several objects or figures are pictured, the line will help to show their size or the relationship among them. The line could mean any number of things—a street, a floor, a tabletop, or the ground.

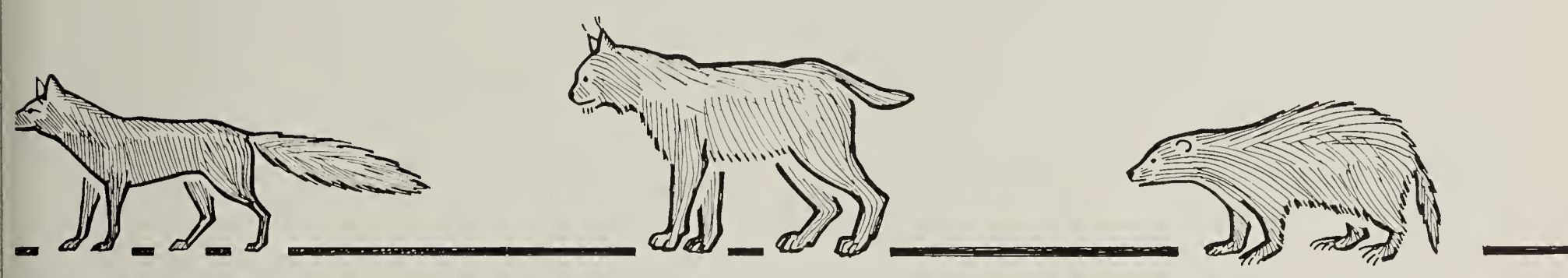
If it is not possible to use a baseline in an illustration showing several objects or steps in a particular process, then use a finely embossed line between forms to lead the reader from one form to another. This is especially useful if the display is made over one, two, or three foldout pages (see A and B).



A. One section of a paper-on-paper buildup display showing the relationship between the limb of a person and that of various animals.

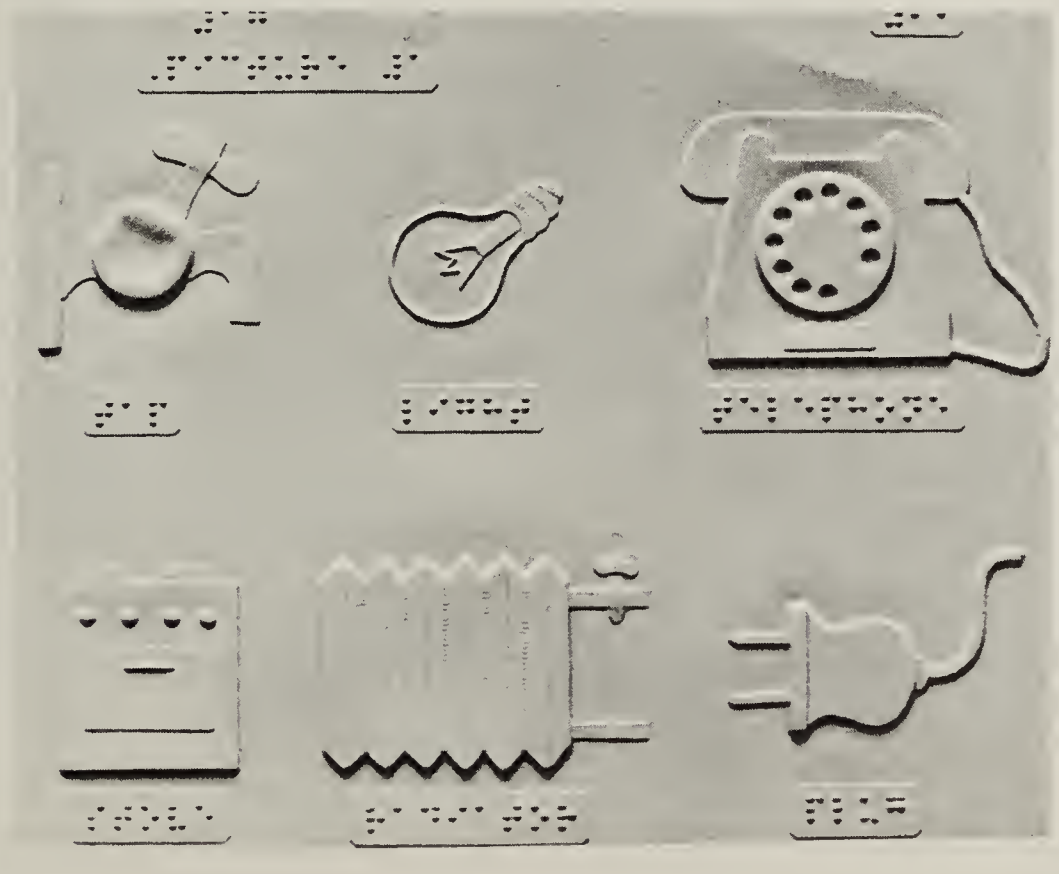


B. The paper-on-paper buildup display as a whole.



SIZE RELATIONSHIP

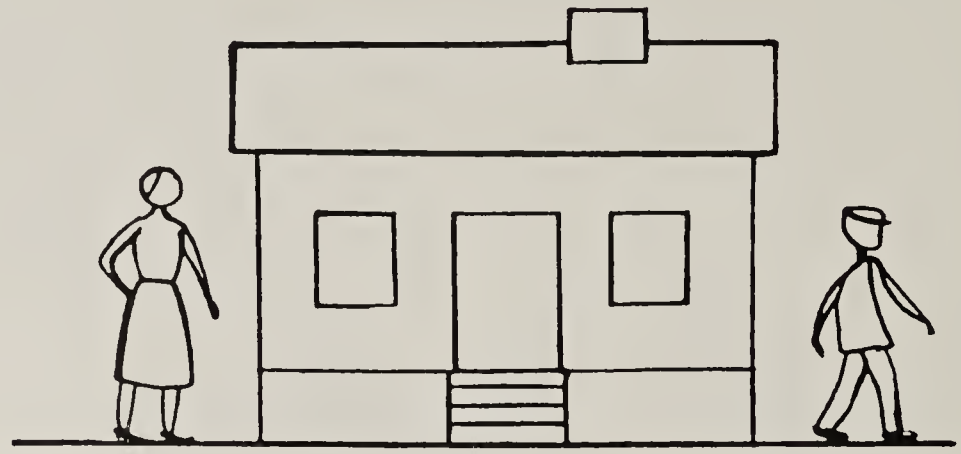
Pictures are a way of presenting an object in relation to its surroundings. Irrespective of whether the object portrayed is larger or smaller than its actual size, the scale of the object should be kept in correct relationship to the objects around it (see below).



In this illustration, there is a complete lack of size relationship among the various objects.

Try to keep the size relationship of figures to animals, trees to houses, and so on as close to reality as possible. A figure

standing beside a house should, theoretically, be able to go through the door of that house (unlike the example here, which shows incorrect size).



Example of unrealistic size relationship of figures to house.

When one object is placed near another rather than being depicted alone, readers can better understand size relationships. A picture of a sunflower, for example, becomes much more informative when a figure is introduced to show the flower's maximum size (see below).

Placing objects next to each other makes their size relationship clear.

Be consistent. If possible, try to keep the objects or figures the same size throughout a single book or picture series. This may be difficult when large objects such as buses are shown with small objects such as cats. A picture description, verbal or

in braille, can help solve this problem. Other exceptions to the rule include children, animals, or flowers that grow up in the story or objects such as balloons or balls that may be blown up and therefore become bigger.

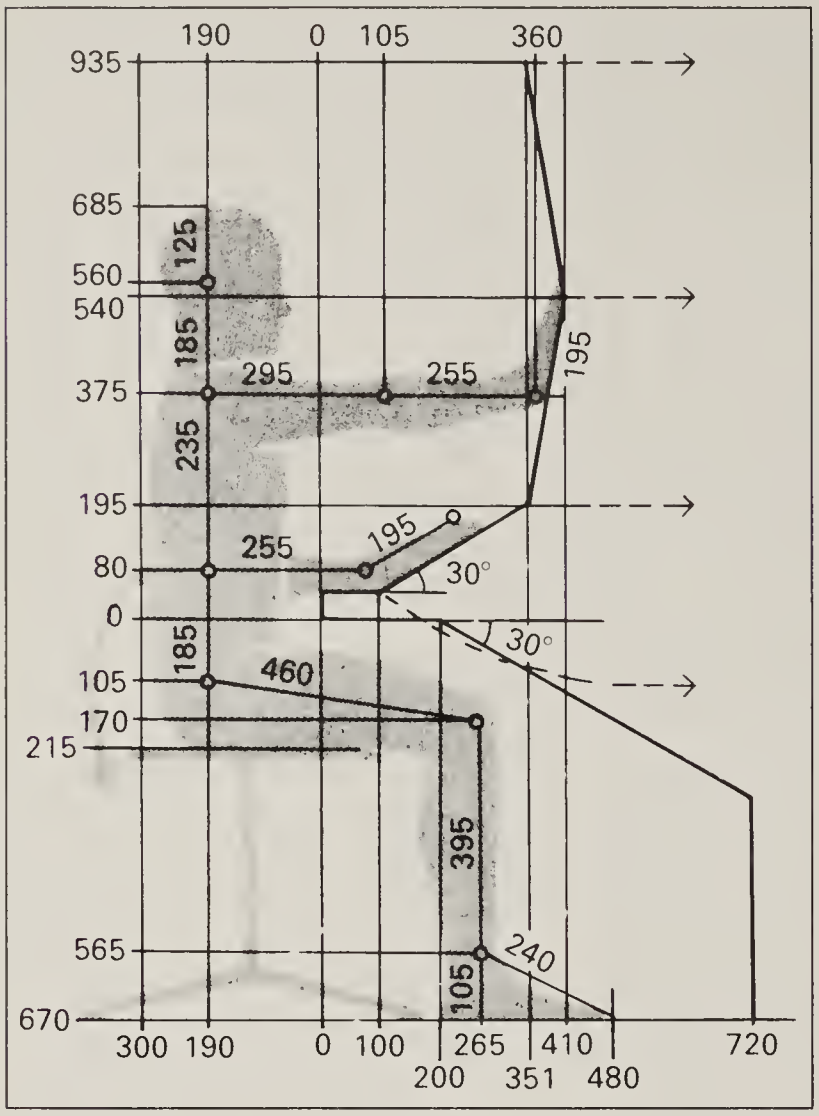
SCALE

Scale is the relationship between the size of a three-dimensional object or area and a two-dimensional picture or map of that same object or area (see also "Scale," Chapter 6). One approach to it is that diagrams should be drawn to scale whenever possible, except when the use of true scale either interferes with the reader's ability to distinguish the objects or produces clutter, or when an enlargement of detail would be instructive and would clarify the object for the reader. In general, when scale is changed, the reader should be informed that the picture is larger or smaller than the actual object portrayed, either through a description of the picture or in braille labeling on the display or on the key sheet accompanying the display. The size can be stated in fractions or in percentages. For example, it can be noted that a picture is one-half or 50 percent of the actual object in size.

Enlarging a picture does not always make it more understandable. There can be drawbacks. First, it may take too long to read an enlarged picture—to understand the connections among the different parts of the layout. Second, the reader may lose the overall idea before he or she has finished scanning the display and may give up entirely.

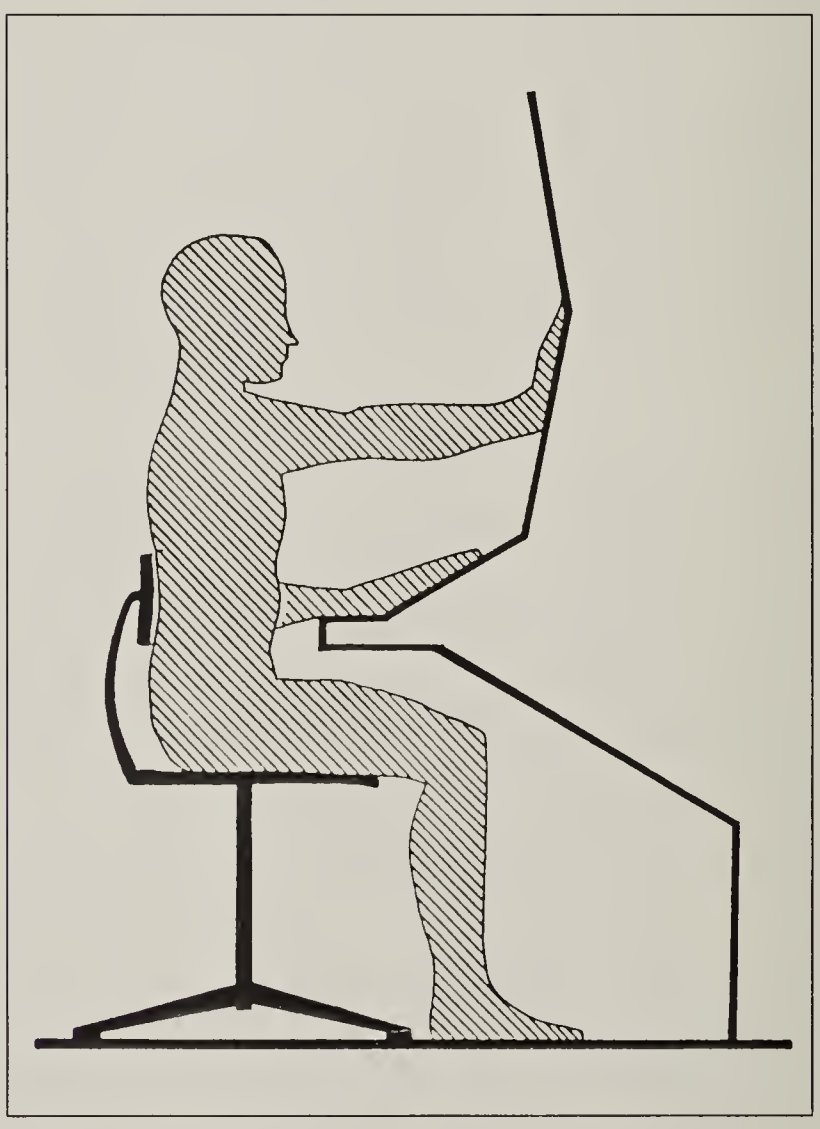
If this might be the case, make two pictures. The first one should be a simple display with as few details or words as possible. The size of the elements of the display should be governed by the ease with which the layout can be read. From this picture, the reader can form an idea of the basic forms and their relationship to each other. The second picture should be made with the desired amount of information. It may be necessary to increase the scale of this display to accommodate details and braille labels. Inform your reader accordingly; remember, he or she will be using the two pictures together. The complicated display for students studying ergonomics shown on the following page in illustrations A, B, and C is an example of the two-picture, two-scale system.

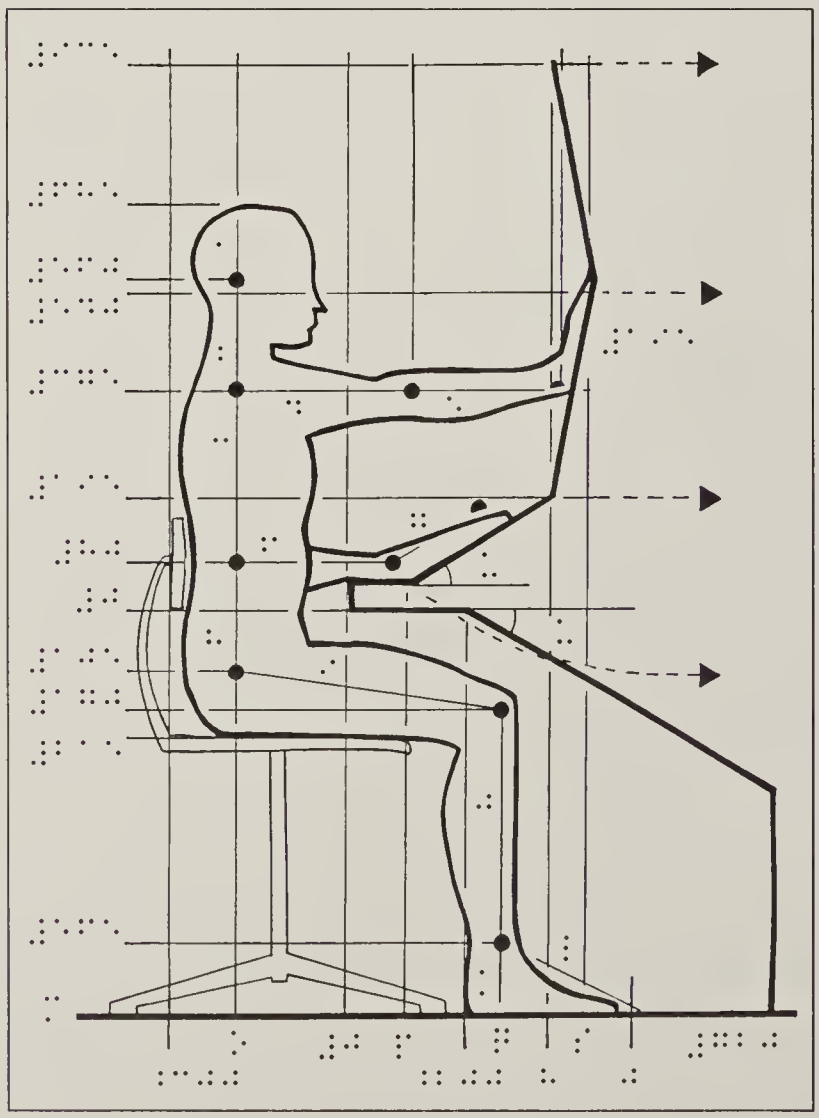
To explain scale to young readers, use a large beach ball,



A. A section of a textbook layout showing a human form and its numerical measurements.

B. Part of the layout showing only the human form.





C. Measurements and the figure seated at a machine.

a tennis ball, a golf ball, a marble, and a pea. All these "balls" have the same form; it is only their scale or size relationship to each other that is different. Ask the children how many peas will fit into the space on a line occupied by a tennis ball and other similar questions.

VARIETY

Figures or objects are often shown in rows in mathematics and language books for young children. When making a tactile graphic display, it is generally not necessary to repeat the variety of position, expression, or type of object as depicted in these books. The information needed to learn the lesson or to solve the problem is usually based on the number of figures presented, not their individual details.

Repeating a single form works well and causes less confusion than using a variety of forms. A form can be represented by a figure, a symbol, or the six-dot braille cell. (See Chapter 6 for easily recognizable symbols that could be used.)

For easy recognition, a figure in a story should have the same clothing (style and texture) and hair style throughout a book, unless otherwise stated in the book. In this instance, variety leads to confusion.

CONTRAST OF TEXTURE

Contrast of texture in symbols used for areas, lines, or points in the same display is of the utmost importance. Without contrast, these areas will blend together and the information they are supposed to give to the reader will not be easily found or understood (see also "Areal Symbols," Chapter 6).

A number of principles should be kept in mind with regard to texture:

- The relationship of objects or items in a display and the contrast or similarity among them are more important to consider than the creation of each individual item. Two or more items created individually without this consideration may vie for importance and give the reader a false or confused idea of the display.
- Choose surfaces that do not feel similar to each other to depict adjacent figures. Otherwise, the forms will become one figure, not two distinct forms. For example, a boy sitting

on a chair can easily become a "chairboy" if contrasting textures are not used.

- Use discretion when choosing symbols and textures. Too many contrasting areas and figures can be bewildering.
- Symbols, labels, arrows, and lines are difficult to find in a textured area. Leave a minimum of 1/8 in. (3 mm) between adjoining tactile symbols for easy readability. (Suggestions for different textures appear under "Tactile-Experience Pictures," Chapter 2.)
- Sharp forms with edges that are perpendicular to the background area and have a flat surface on top (see A) are more noticeable than rounded forms (see B).

A. B.

- Your fingers should be the final judge of the textures used in a display.

LABELS

Braille labels, figures, or numbers should be close to the point that they define. There should be no question about what they identify, but they should in no way obstruct the point, line, shape, or symbol they delineate. They are there to inform, not to complicate the diagram or hinder the reader from understanding the overall picture.

Suggestions

- Keep in mind the 1/8 in. (3 mm) limit, and do not place a braille label or character closer than that distance to the item it identifies. This distance should be increased if the braille is close to a highly elevated shape or line so that the reader will not skip over the braille when feeling the display.
- Labels in textured areas are difficult to read. Allow for increased space around the braille, especially in dotted areas, where the braille could blend into the texture and be lost.
- When using the microcapsule paper technique (see "Microcapsule Paper," Chapter 2), remember that the height of all lines, textures, symbols, and braille is the same. Allow enough free area around the braille so that it can be easily read.

- Close placement of a label to its item may not always be possible. When this is the case, use a braille figure or letter instead of a name label. Include an explanatory key on the diagram, adjoining page, or facing page, or on a foldout page. As an alternative, arrows or lead lines can be used to connect the label with the point in question. This technique, however, is a last resort. Lead lines often become an integral part of the picture and so can add to the reader's confusion.

  If lead lines are necessary, do not make them prominent. Use thin thread or make a fine embossed line with a spur wheel.

  Be sure that the texture of these lines is completely different from the other line symbols in the diagram. Try to keep a lead line short, no longer than 3/4 in. (2 cm).
- When an object, symbol, shape, or line appears several times in a display, do not hesitate to label it each time. Fingers do not derive an overall picture of a display at once. The reader must feel his or her way through the diagram, adding information together bit by bit.
- Try to be consistent in placing labels in a diagram. If possible, place them on the same side of the various points in the diagram. This is difficult to do when the diagram is complex and labeled areas are so small that a single figure or number is used in connection with a key. Use your discretion. The main point is to keep the display uncluttered and to lead your reader through it with the least amount of effort.

Other Points to Remember

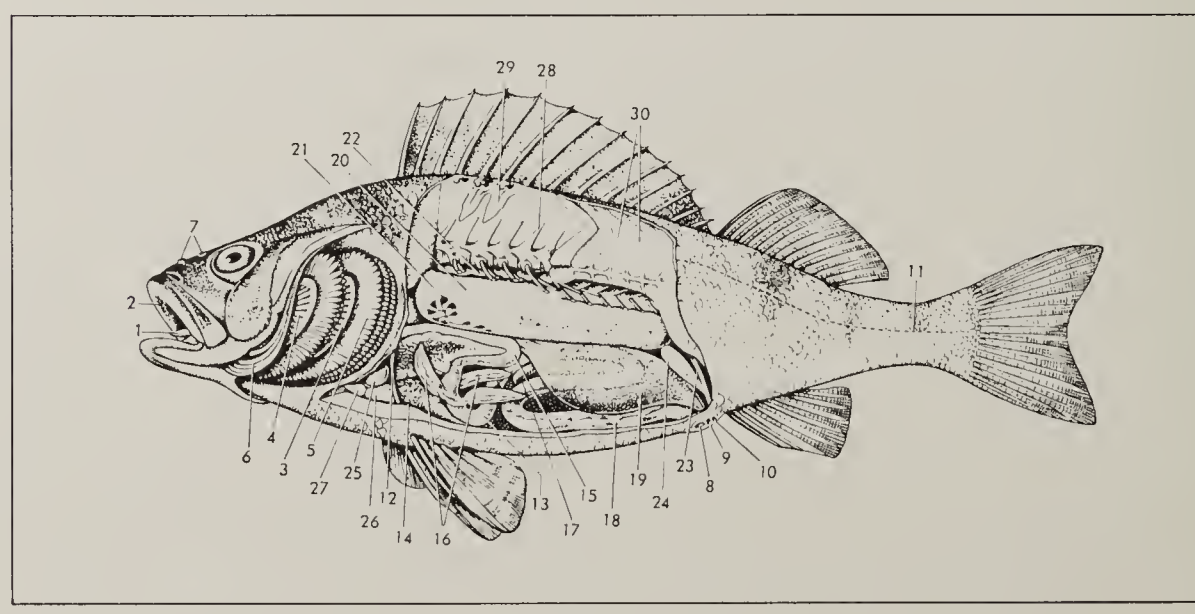
- Numbers, letters, words, and texts, written in braille and cut into strips or small labels and glued into a display, tend to create distracting boxes in a picture. If possible, plan the placement of the braille before constructing a master. Braille the necessary sections before gluing the various materials and forms onto the background or into the display.
- Decide where the text should be placed in the display when dealing with braille made with a writing slate and stylus and embossed on the back side of the display. Mark the text area by pricking the braille paper with a fine needle. Turn the paper over and circle the tiny hole with a pencil. Adjust the writing slate within the marked area.

- When making a master, brailling an area first may not always be possible because of the placement of the brailled area or the thickness of the material to be brailled (each display creates its own problems). In such cases, separate labels or text, glued into place, seem to be the only solution.
- To emphasize certain symbols, words, or text, braille them separately, mounting them on an additional thickness of braille paper, and glue the label onto the display. The raised relief area will stand out from the other brailled details in the display and catch the attention of the reader's fingers.

WORDS, DESCRIPTIONS, AND TITLES

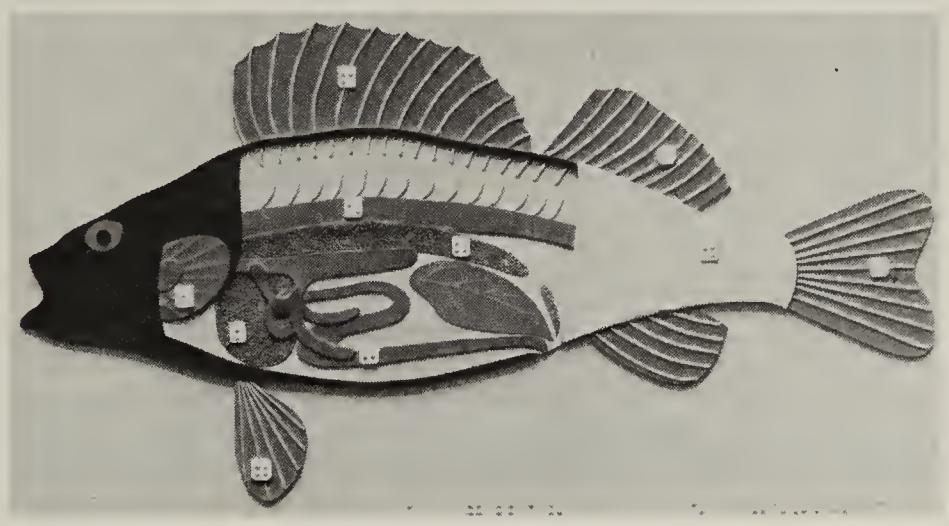
The reader should not be misled into thinking that letters, numbers, and words within the picture area are part of the object being illustrated. Otherwise, great confusion can result. Remember that they are nothing other than braille information.

A case in point is a display of a cross section of a fish made with reference to the textbook illustration shown here (see A). The master maker thought it necessary in making a display to label the parts of the fish's body with letters (see B). This would have been all right if the letters had not been cut to a minimum size (a four-dot cell) and the corners of the labels had remained square. However, when the small, somewhat rounded labels were glued into place, there was a definite similarity between them and the fish's eye. According to the children who used the display, this was a many-eyed fish, and they believed this despite the fact that they could read braille and understand the key that accompanied the display.

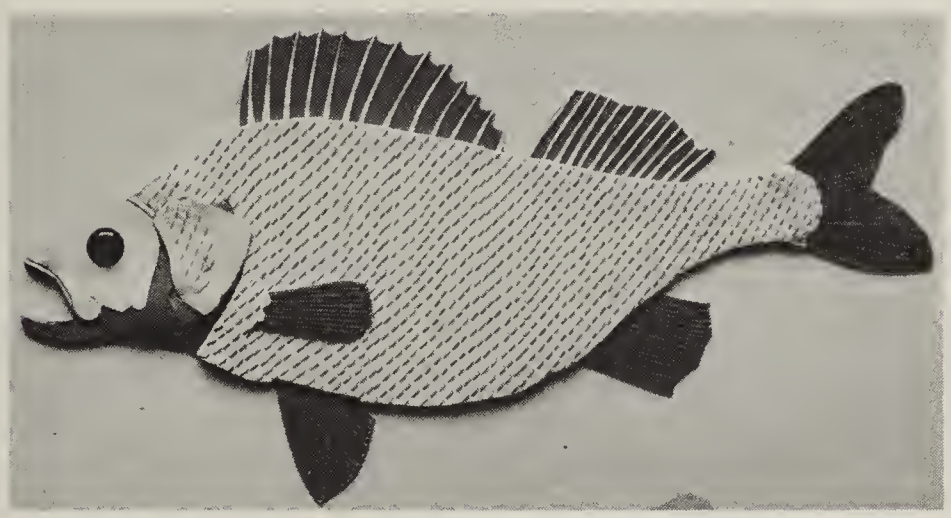


A. The textbook illustration.

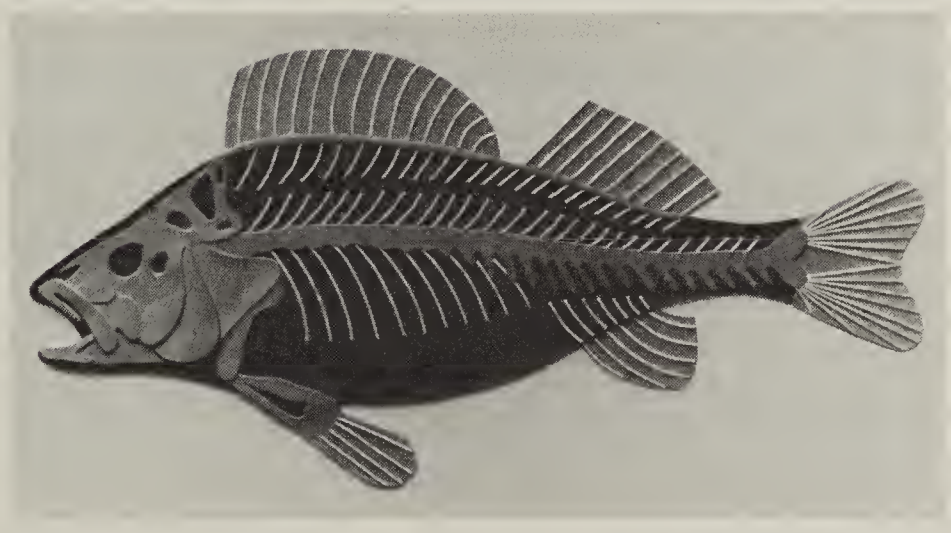
This fish was so confusing to the children that it was redone in a series of three pictures: the exterior of the fish as a whole, the fish skeleton mounted on a flat undetailed fish form, and



B. In this display, letters are confused with parts of the fish shown.



C. The series of three displays used to eliminate confusion.



the entrails of the fish placed within the outline of the fish (see C). In this series, the different parts of the fish did not overlap with each other, and it was easier for the reader to understand each part. In addition, the letters on the fish were eliminated, as was the key. Instead, a sheet of numbered braille words accompanied the three displays. The teacher using them could cut out the words and have the students fasten them on the fish temporarily or could braille as many numbers as there are words on the braille sheet and ask students to place the numbers in their proper places on the displays. This system actively involves the reader and increases the knowledge he or she retains.

Descriptions

A title, words, or a short description at the top of a display page can be useful to lead readers into the picture, especially if they are to use the material unaided. Comprehension of the display is increased when the reader is told what he or she will be feeling. Many readers express a desire for a name or several words to be printed under the relief figure as well. This repetition organizes the picture information in the child's mind. (It is, however, unnecessary on illustrations for older students.)

Keep descriptions as short and concise as possible. Even a small message becomes a large one when printed in braille. It is important to remember that young readers are not too adept at reading braille at the beginning of their education.

When converting printed textbook material into a relief display, remove all unnecessary text, lines, or areas that could be confusing to the reader. This is an important editing procedure and applies to the transformation of all forms of visual graphics.

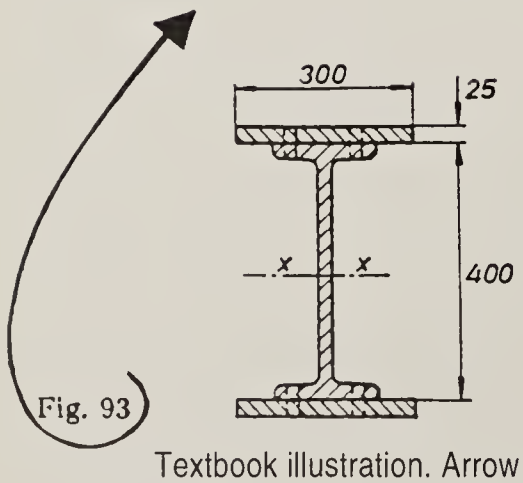


Fig. 93

Textbook illustration. Arrow indicates appropriate placement of figure number.

Words and arrows in the picture area, when not absolutely necessary, tend to clutter the area. Use them with caution.

The figure number or title of the display should correspond to the one in the printed material unless otherwise stated. This information should appear above the illustration and to the left of it, irrespective of where the number or title is located on the printed page.

Important information concerning the relief displays of a book that may not be included in the printed textbook version should be presented to the reader in the foreword or begin-

ning of the braille book. This information may include the use of directional reading arrows, a certain symbol for a particular letter combination that appears throughout the displays, special layout features, and so on. As separate unbound relief material, pictures, graphs, and maps should be accompanied by braille or audio instructions and descriptions, if deemed necessary. Young readers and those persons not able to read braille should have access to descriptions and instructions of their relief material on tapes (i.e., cassettes).

Page Numbers

The two methods that are in use at the present time to place page numbers on relief materials are:

1. The braille page number is placed in the upper right-hand corner of the page. If the page is transposed from printed material, the inkprint page number is usually printed in the upper left-hand corner of the page on a line with the page number of the braille book.
2. The braille page number is placed in the lower right-hand corner of the page. The inkprint number is printed on the same line in the lower left-hand corner. This system seems to make it easier for young children to find the right page more rapidly and with less effort. They do not have to stretch all the way across a large braille book to find the number. It is as close to them as the bottom edge of their book.

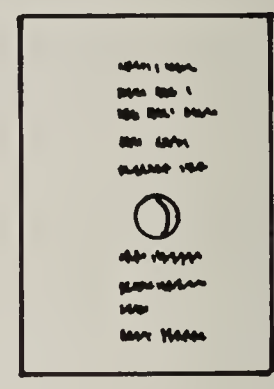
Titles and figure numbers of relief displays should be placed on the top left-hand side of the page. If page numbers come first, place the title or figure number under the page number.

Written descriptions for pictures in a question-and-answer situation often appear in workbooks that accompany the textbook for certain subjects, such as mathematics or geography. Place the descriptions above or to the right of these pictures, diagrams, and maps (see mention of low-relief displays, in "Paper-on-Paper Buildup Displays," Chapter 2) if the answers are to be written on a braillewriter. This enables the reader to read the text before writing his or her answer without removing the page from the machine. Place descriptions under the picture, map, or diagram if the answers are not to be made on the same sheet as the display.

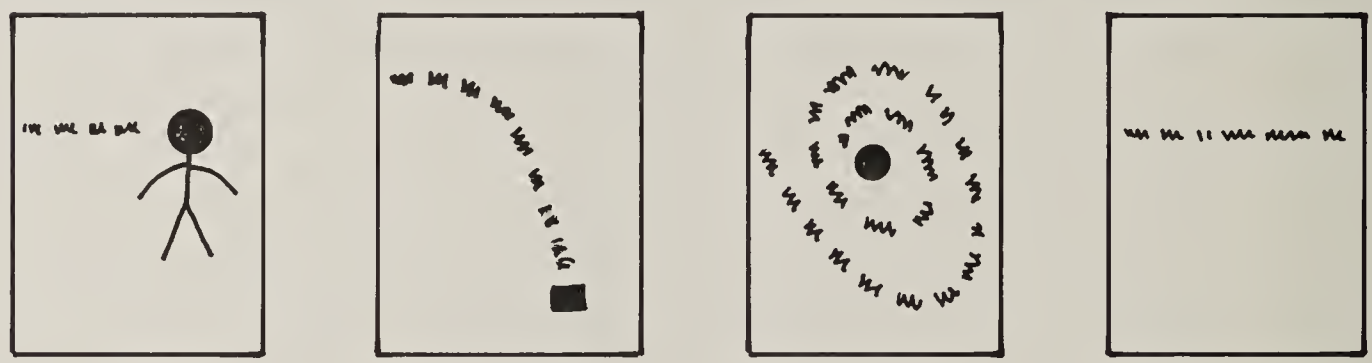
Braille as a Graphic Component

Words in a picture should convey information but should not mislead the reader. Words can convey information in a graphic way, as the illustrations shown here demonstrate. This technique is mainly for beginning readers or for books that are to be read by young sighted and blind children together.

A braille text became a tree trunk in *Mallan Meets Mulle*, a book about a wood mouse (Flodin & Edman, 1971). (The words on these pages were done with a slate and stylus on braille paper.) Each word was placed directly under the preceding word, from the top to the bottom of the page. A hole in the trunk of the tree was cut through the page. The reader can poke a finger through the hole and feel a furry animal on the next page.



Words can also lead the reader into a display or through a page.



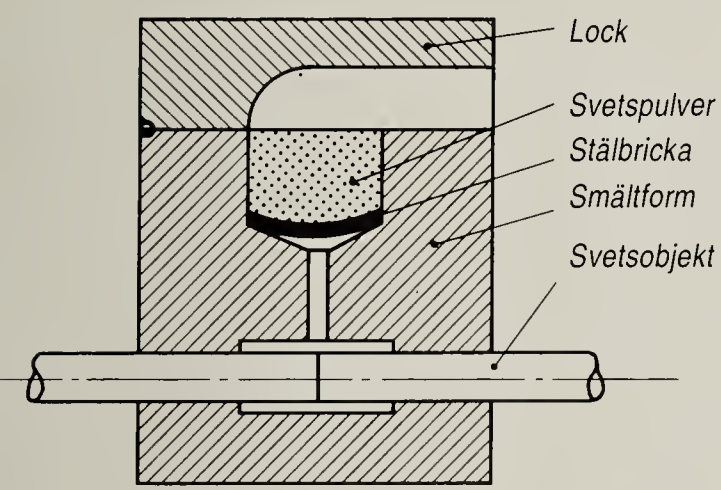
Words can act as stairs, going up or down, or be a simple route from one place to another.

But remember, this type of word graphics needs some sort of description from those who are reading to or with the young reader. The picture may not be as self-explanatory as it seems to you. In Uruguay, this technique is called moving braille. It stimulates the blind child to action and reaction. The child must use his or her hands in order to explore the lines and is stimulated to find the beginning of the line, which is not always in the upper left-hand corner of the page.

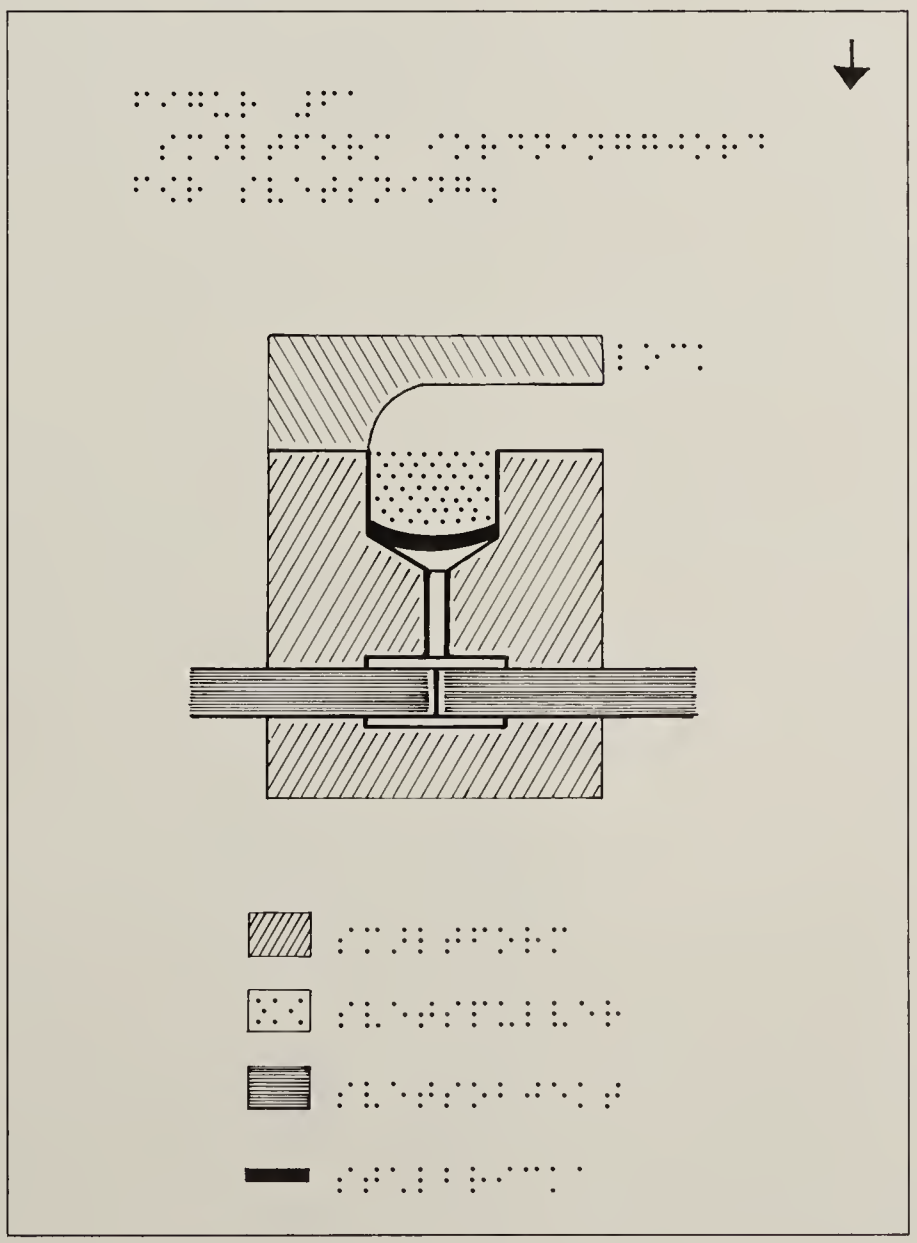
KEY OR LEGEND

A key is a list of explanations of symbols, lines, textures, figures, and numbers. Although a key is most frequently associated with maps, it can also be a vital component of a complex picture, as shown by the legend used with the braille master illustrated here.

Extraneous material, such as text, labels, and arrows, becomes an integral part of the picture if included in the relief display. Avoid this, as far as possible, by using a key. Textures, single letters or numbers, or other symbols, placed on or near the desired areas, will help reduce the reader's confusion. Letters and numbers here mean both braille and inkprint characters. The choice depends on who will read the display.



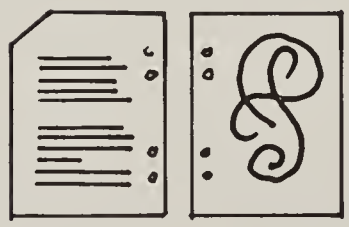
In the braille master shown here, a legend replaces the labels used in the original illustration from a Swedish textbook.



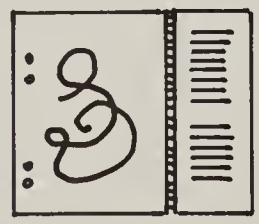
- Textures, lines, and symbols are usually placed first in a key, followed by individual words, abbreviations, letters, or numbers. Letters are usually listed in alphabetical order, and numbers in numerical sequence.
- The purpose of the key is to relate letters and abbreviations to particular words. These letters need not be connected with the word they represent. However, single letters or a combination of letters that have something to do with the name of the particular object they modify are more easily remembered than letters picked at random (such letters must be constantly referred to in the key).
- Braille letters K through Z are most useful in a diagram. There is little chance of confusing them with braille numbers, which are the letters A to J preceded by the number symbol.
- Small-character braille, sometimes called English microbraille, is suitable to use on pictures and maps when the brailled area is not large enough for standard-size braille characters. It is not advisable to mix braille characters of different sizes in the same diagram unless it is absolutely necessary to do so. Small-character braille should not be used for students below the high school level or for some adult readers. If microbraille is used in the display, use the same microbraille character in the left-hand column of the key. The description of this character in the right-hand column of the key should be made in standard braille.

The following are the three ways to place the key to a diagram that is included in a braille book:

1. It could be placed directly on the diagram, provided there is enough room on the layout. In no way should a key become a confusing part of the actual picture.



2. It could be placed on a facing page.



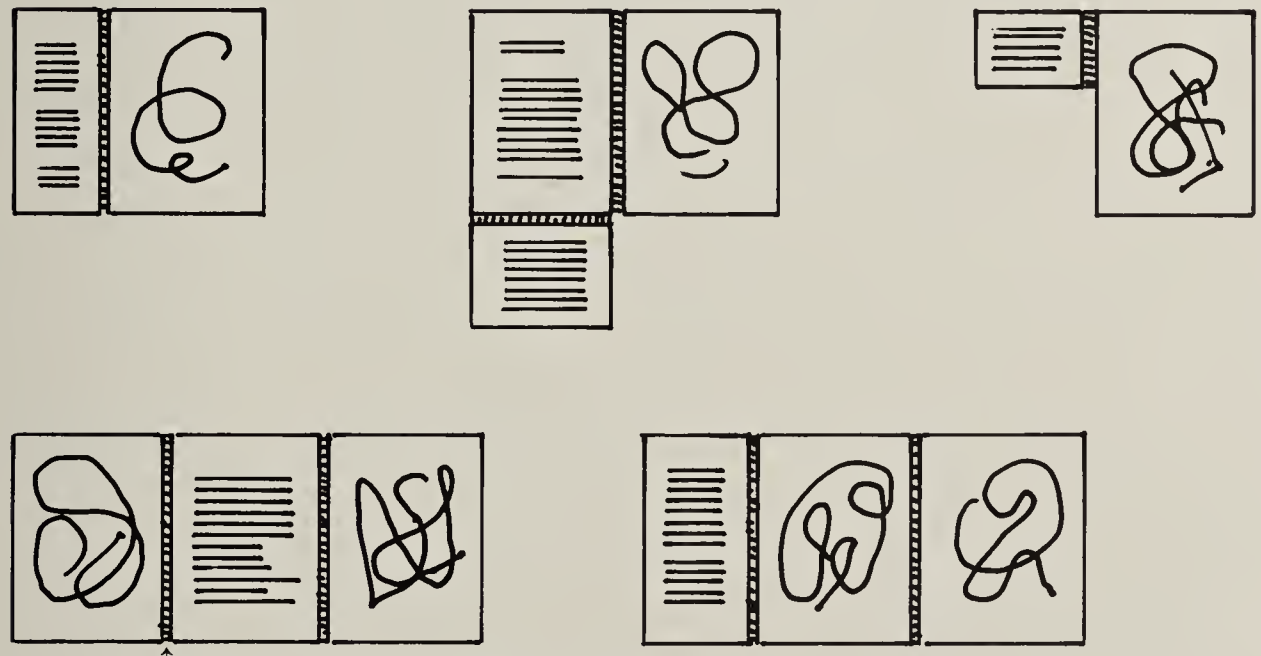
3. It could be attached to a diagram as a foldout page, a half page, or part of a page.

Note that the placement of the key should be consistent throughout each complete set of diagrams.

If the diagram is to be used as a loose sheet, the key could be attached to it in much the same way as the diagram in a book, provided that the key is not too large in size. It is easier for the blind reader to have the key attached to the material permanently, rather than by a paper clip.

There are several ways to attach a key, as shown here, depending on its size and the amount of display material. All the pages shown here are fastened together with tape that will not dry out, crack with use, or become sticky with age, such as white flexible 3M Micropore surgical tape. This tape is available from the 3M Company (see Appendix 3 for address) in 1/2 in. (12.7 mm) and 1 in. (25 mm) widths.

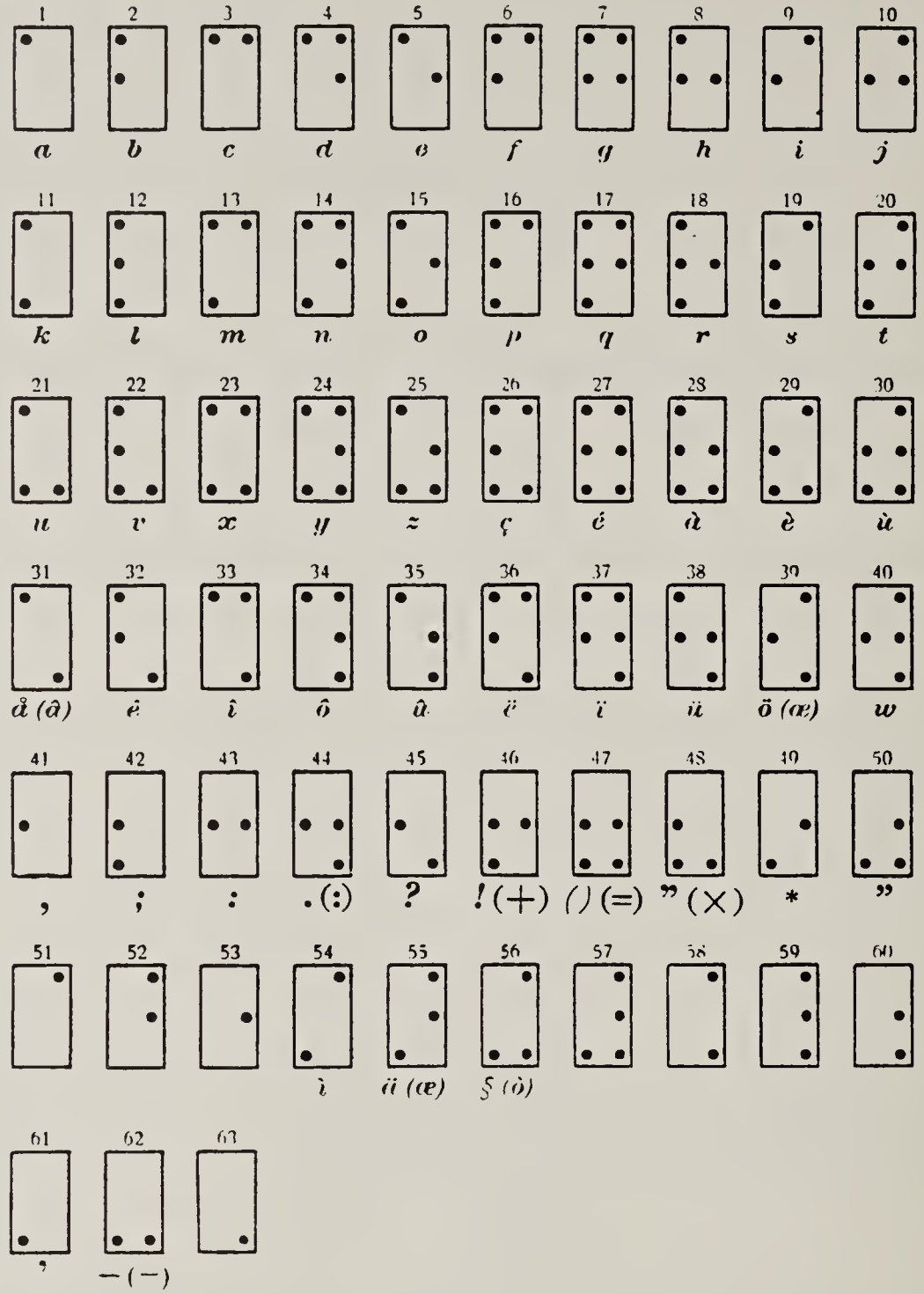
A separate key is recommended if there is a chance the material you produce will be used by other countries at some future date. The key would then be translated into other languages and fastened to the display (a possibility shown here).



About .04 in. (1 mm) between the two sheets

BRAILLE

Braille, the universally accepted system of writing used by and for blind persons, consists of a code of 63 characters, each made up of one to six raised dots arranged in a six-position matrix or cell. The following is an illustration of braille numbers and letters that includes punctuation symbols and diacritical marks used in several languages:



1 • • 4
2 • • 5
3 • • 6

For the purpose of identification, the dots have been numbered downward, 1, 2, and 3 on the left, and 4, 5, and 6 on the right. The first ten letters of the alphabet, A to J, are formed with dots 1, 2, 4, and 5. When these letters are preceded by the number sign ⠼, they become the numbers 1 through 9 and 0. The letters K to T are formed by adding dot 3 to letters A to J. The letters U, V, X, Y, and Z are formed by adding dots 3 and 6 to letters A to J. W is formed by adding dots 6 to the letter J. *Note: World Braille Usage* (Dixon, 1987) covers braille codes for literary, mathematical, scientific, computer, and musical materials (see Appendix 4 for further information).

Japan is interested in using an 8-dot braille code (Sueda, 1985). The aim is to develop a universal braille code with letter-

to-letter correspondence between braille and inkprint letters, including Japanese characters (kanji). With this system, it would be possible to make free combinations of various mathematical, physical, and chemical symbols; to translate music scores into normal Japanese sentences; and to facilitate the writing of computer programs. The 8-dot braille code is based on the 6-dot standard braille code with an additional two dots placed above dot 1 and dot 4.

糸 ⣿ (Ito-Hen)	系 ⣿ (2nd Ito-Hen)
家 ⣿ (U-Kanmuri)	宿 ⣿ (2nd U-Kanmuri)
学 ⣿ (Tsume-Kanmuri)	言 ⣿ (Gon-Ben)
語 ⣿ (2nd Gon-Ben)	頁 ⣿ (Oogai)
貝 ⣿ (Kogai)	金 ⣿ (Kane-Hen)
木 ⣿ (Ki-Hen)	草 ⣿ (Kusa-Kanmuri)
犬 ⣿ (Kemono-Hen)	子 ⣿ (Ko-Hen)
都 ⣿ (Oozato)	市 ⣿ (Haba-Hen)
発 ⣿ (Hatsunobori)	食 ⣿ (Shoku-Hen)
馬 ⣿ (Uma-Hen)	田 ⣿ (Ta-Hen)
竹 ⣿ (Take-Kanmuri)	土 ⣿ (Tsuchi-Hen)
手 ⣿ (Te-Hen)	戸 ⣿ (To-Kanmuri)
人 ⣿ (Nin-Ben)	仁 ⣿ (2nd Nin-Ben)
水 ⣿ (Sanzui)	氷 ⣿ (2nd Sanzui)
力 ⣿ (Chikara-Hen)	示 ⣿ (Shimesu-Hen)
私 ⣿ (Nogi-Hen)	走 ⣿ (Soo-Nyo)

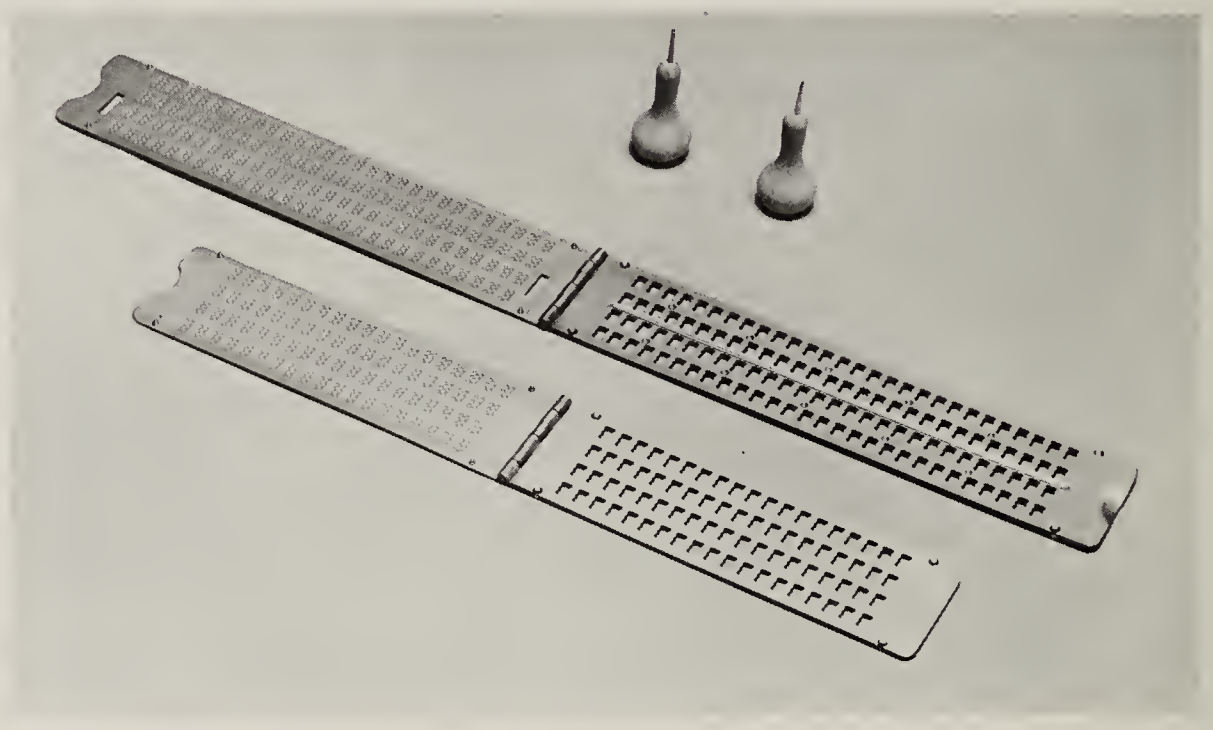
Primary basic kanji braille.

Discussions concerning an 8-dot braille cell have come up in various parts of the world for many years. The increasing use of computer braille may lead to further discussions—as in

Japan. However, in this handbook the only braille used is based on the 6-dot braille cell.

There are several ways in which to write or produce braille, ranging from the simple slate and stylus to a computer system and a braille printer. The easiest way to write braille when making tangible graphic displays is with a freehand drawing stylus (see "Embossed Paper Displays," Chapter 2), a slate and stylus, a braillewriter, or instant dry-transfer braille cells (described later in this section).

Braille Writing Slates



A braille writing slate.

A braille writing slate is a folding metal or plastic frame, available in various shapes, from pocket size to desk size, and in three different braille-dot sizes: standard braille, microbraille, and jumbo braille. The frame can be used with a light or heavy grade of braille paper. It can also be used on thin plastic sheets, .006 in. (.15 mm). The braille alphabet, written in reverse, is depressed into the paper by pressing a stylus through the openings in one side of the slate frame. When the paper is reversed, the braille dots will be embossed and in their right positions.

Most frames are made with small pins or pegs that are meant to hold the paper in place when they are being used. If the frame is to be used in making relief displays, I suggest that these pins be filed down flush with the frame to eliminate unnecessary holes in the braille paper that is used in the display. Firm pressure on the frame will keep the paper in place

without these pins. The Marburg braille writing slate, a full-page plastic braille slate, has 27 lines with 30 cells each to make maximum use of paper sized 8 in. by 12 in. (20.3 cm by 30.5 cm). With this slate it is possible to write on both sides of a sheet of paper in interpoint, which means that the characters on the second side of the paper are produced between the points of the characters on the first. The slate is available from Deutsche Blindenstudienanstalt. A variety of slates are available from the American Foundation for the Blind (AFB), American Printing House for the Blind (APH), Howe Press, and the Royal National Institute for the Blind (RNIB) (see Appendix 3 for addresses).

- The microbraille or small-character braille slate is most useful on pictures or maps where the area to be brailled is not large enough for the standard-size character. It consists of seven lines of 23 cells each. It is called the Tylor-Tatlow Frame and is available from RNIB.
- Jumbo-braille, also called giant-dot or oversized braille, slates are useful when making displays for beginning readers or for those visually impaired persons who have difficulty reading standard braille characters. Howe Press is experimenting with standard-size braille within a jumbo-braille cell for people with reading problems.
- The single-line slate, consisting of 25 standard-size braille cells, is useful for making self-adhesive relief labels. The slate folds over a 3.8 in. (1 cm) tape. It is available from Howe Press.

A single-line slate.

It is not advisable to use self-adhesive plastic tape like dymo embossing tape on a master that will be duplicated in the vacuum-forming machine unless the tape has been tested for heat resistance. Several of the standard brailling slates are made with slots for dymo-tape embossing.

- Correction slates, made primarily for proofreaders who correct assignments produced on a braillewriter, are 40-cell, 4-

line slates that have the distinct advantage of being able to reach further into a display than any of the other slates. These slates are available without paper-holding pins.

Remember that the white area, or empty space, around a braille character or word is most important! Allow 1/8 in. (3 mm) or more to the nearest line, texture, or shape (see "Point Symbols," Chapter 6; for the placement of braille, see "Labels," this chapter).

Braillewriters

A variety of machines can be used to produce braille. The J. Perkins Brailler is a well-established machine that is widely used throughout the world. The machine writes on one side of the paper, enabling the braille to be read as it is written. It accommodates paper up to 11 1/2 by 14 in. (29.2 by 35.6 cm), permitting 25 lines of 41 cells on a page. The machine is built to provide a lifetime of service in all climates.

The Perkins Brailler.

Two sizes of braille text are available: standard and jumbo. These machines can be purchased in a manually operated or electrically operated version from APH, Howe Press, and RNIB.

The new Generation SK 300 Marburg Braille Machine produced by the Deutsche Blindenstudienanstalt is the most recent addition to the international field of braillewriters. It has the following features:

- Maximum paper width: 11.8 in. (30 cm).
- Maximum cells per line: 44; space between cells : .236 in. (.6 cm).

The Marburg Braille Machine.

- A movable embossing head, which allows the writer to read the braille character just written.
- A tabulator for writing tables and a tabulator key that also has a release function.
- An adjuster to adjust line spacing to three different sizes.
- A warning sound to notify the writer of the last five braille characters and lines.
- An attached reading board, which will accommodate five lines.

This machine is available from the Deutsche Blindenstudienanstalt and its U.S. representative, Braille International (see Appendix 3 for address).

The Mountbatten Brailler is a full electronic machine for typing 6-or 8-dot braille. It will erase mistakes automatically. It has a memory facility for completely silent braillling (i.e., one can type into the memory and print later), and there are automatic tab stops and margin settings. It can be connected to a computer or an electronic printer. The Mountbatten Brailler is available from Quantum Technology pty Ltd. (see Appendix 3 for address).

The Erica 500 Braille Writer is a sturdy machine with a simple construction and requires little maintenance. It is made for writing on one side of braille paper using the six-point braille system. The width of the carriage is 10.6 in. (27 cm). It has an immobile embossing head, and the carriage runs on ball bearings. Standard character spacing is .24 in. (6.1 mm).

The Mountbatten Brailler.

The machine comes in several models to accommodate various physical disabilities. One model has a .28 in. (7 mm) character spacing for improved readability; it is especially good for persons who become blind late in life. The machine is available from Deutsche Blindenstudienanstalt.

The Stainsby braille writer, for producing standard-character braille, consists of an aluminum alloy board on which the machine, comprising a movable bedplate with sliding carriage and key mechanism, is placed. The carriage travels from right to left as the braille is written. As each line is finished, the machine is moved down to the next set of holes on the board.

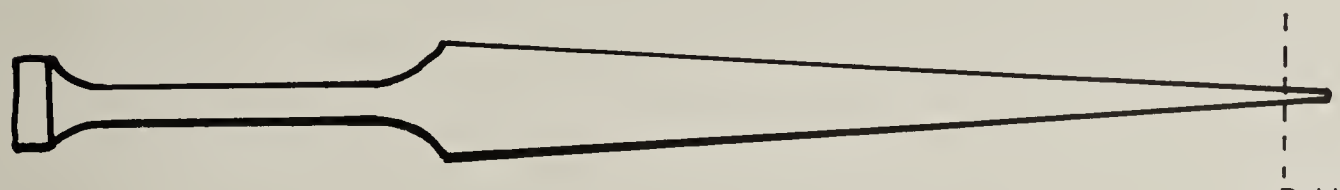
The writer, available from RNIB, comes in three standard models, all of which use 10 in. by 13.5 in. (25.4 cm by 34 cm) paper:

1. Interlining model for producing braille with the characters on the second side of the paper between the lines on the first.
2. Interpointing model for producing braille with the characters on the second side of the paper between the points of the characters on the first.
3. Combined model for producing both interline and interpoint braille.

Erasers

There are both wooden and plastic erasers for use with braille. They are often made so that the small tip may be used for erasing one dot at a time. The larger end is suitable for erasing an entire cell at one time.

A wooden bobbin used in weaving makes an excellent eraser. Sand down the pointed end to accommodate the size of a braille dot.



Bobbin used to erase braille *(actual size).*

When erasing a dot, letter, or word, it is often advisable to put a thin transparent tape on the reverse side of the paper to ensure that the erased dot stays in place. Be sure that the tape is heat-resistant if this paper is to be used in a vacuum-forming machine. Scotch™ Magic Transparent Tape, made by the 3M Company, has been well tested for this purpose.

Braille characters and embossed areas on paper tend to flatten and wear out when the display is used a great deal or when it is used often to mass-produce copies by the vacuum-forming process. To help prevent this wear on displays, spread putty (a mixture of whiting and boiled linseed oil, kneaded to a consistency of dough, which is often used to fill cracks in woodwork and to fix window frames) thinly over the back side of the display with a spatula. Leave only the putty that fills up the braille dots or the embossed areas; scrape off the rest. Shellac can also be used on the back side of the paper. The result, however, is not as good as putty, since the braille dots become quite sharp.

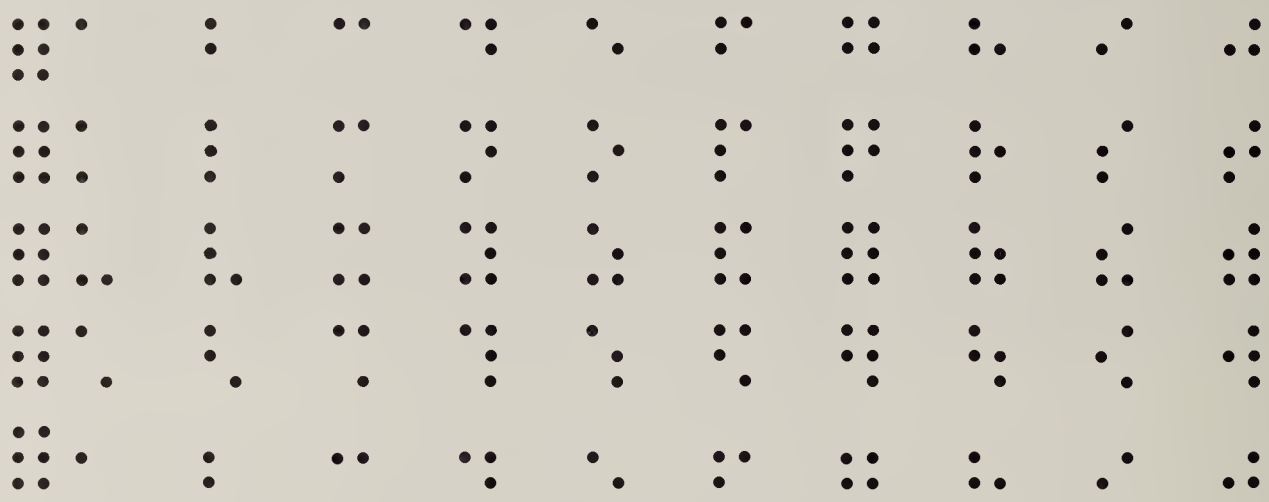
Braille in Cramped Quarters

When it is necessary to place a letter or number in a layout but space is limited, you can:

- Write braille with a small-character braille slate (microbraille),
- Substitute letters or numbers for the braille information (explain these substitutions in a key and be sure that you do not repeat single letters or numbers that already exist in the diagram),
- Use letters instead of numbers to eliminate the number sign before the figure and save space.

For crossword puzzles, calendars, and so on, use a braille letter, without the number sign, in each square for numbers 1 to 50. For 1 to 10, use the standard braille letters A to J as a basic

form. Numbers 11 to 20 are made by adding dot number 3 to the basic figures. For numbers 21 to 30, add dots number 3 and 6 to the basic figures, for numbers 31 to 40, add only dot number 6 to the basic figures, and for numbers 41 to 50, move the basic figures A to J down one row to a lower position in the cell form.

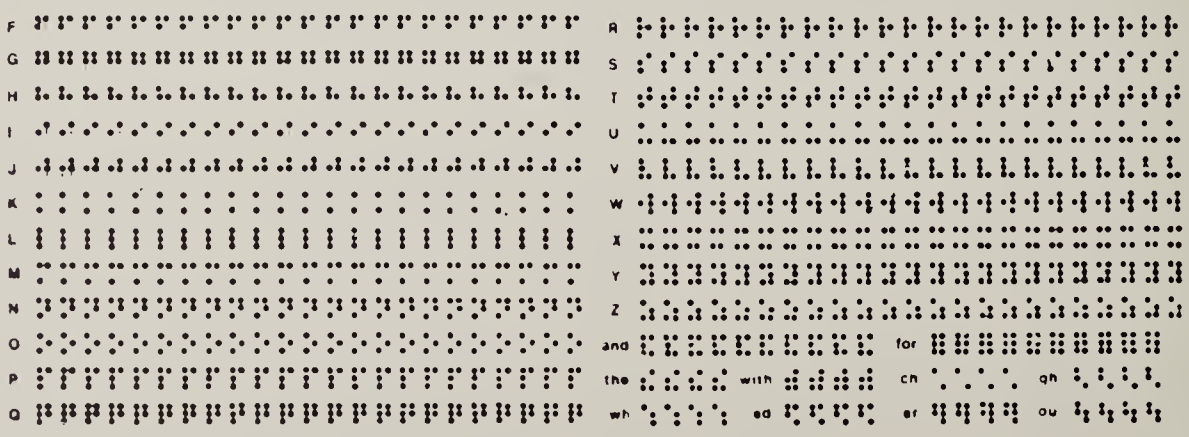


Braille adjusted for limited space.

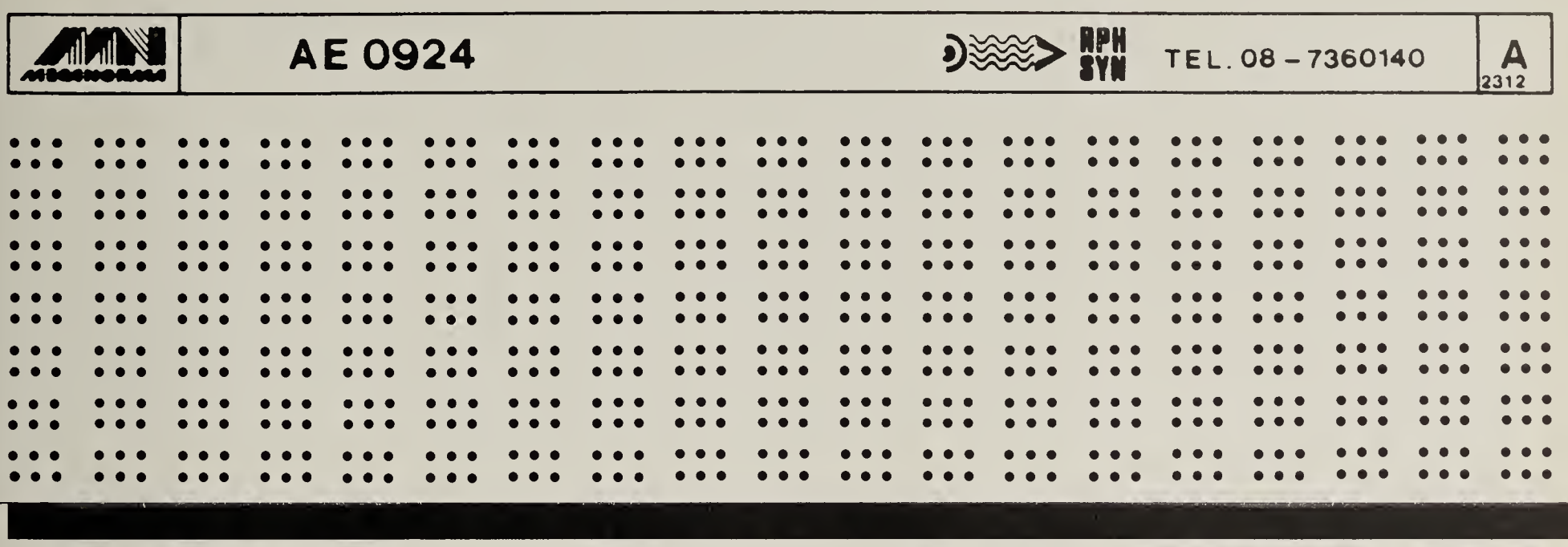
Instant Dry-Transfer Braille Symbols

Instant dry-transfer sheets, often called rub-on braille, are used on original layouts for microcapsule paper displays. The black symbols are printed on the back of a thin sheet of transparent plastic. The braille characters are transferred to the desired background by rubbing the plastic with a pencil or with a wooden or metal stylus.

An instant braille alphabet sheet developed in Australia contains standard-size braille characters and several braille symbols. It can be used by people who do not have a working knowledge of the formation of braille characters. (For information, contact the Australian Institute of Cartographers; see Appendix 2 for address.) The portion of the alphabet shown here is greatly reduced in size to allow an extensive part of it to be seen.

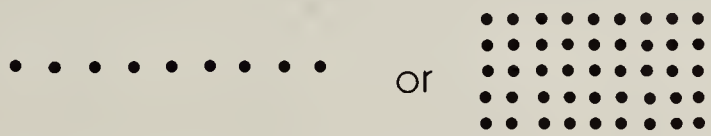


Braille alphabet for rub-on lettering, developed in Australia.



Top part of an instant braille transfer sheet produced in Sweden.

The instant braille transfer sheet produced in Sweden, part of which is also shown here, contains hundreds of standard-size braille cells. Complete words and sentences can be brailled at one time without moving the transfer sheet to form a new letter. The unused dots remaining on the transfer sheet can be used to form additional symbols, letters, and numbers wherever needed. The remaining dots on a well-used transfer sheet could be used as texture or as a line symbol in an original layout.



The sample shown is actual size. It is part of a sheet 11.8 in. by 8.3 in. (30 cm by 21 cm) produced by Mecanorma of Sweden but available exclusively from RPH-SYN, the National Center for Educational Aids for the Blind (see Appendix 3 for address).

The life span of all instant dry-transfer characters and textures is limited. The unused sheets should be stored in a closed box in a cool and dark area for maximum shelf life. Do not store them in a refrigerator or freezer.

There are several ways of mass-producing braille texts. However, this handbook is concerned with tangible graphics and does not deal with the production of braille itself. Therefore, the following methods are mentioned only in passing:

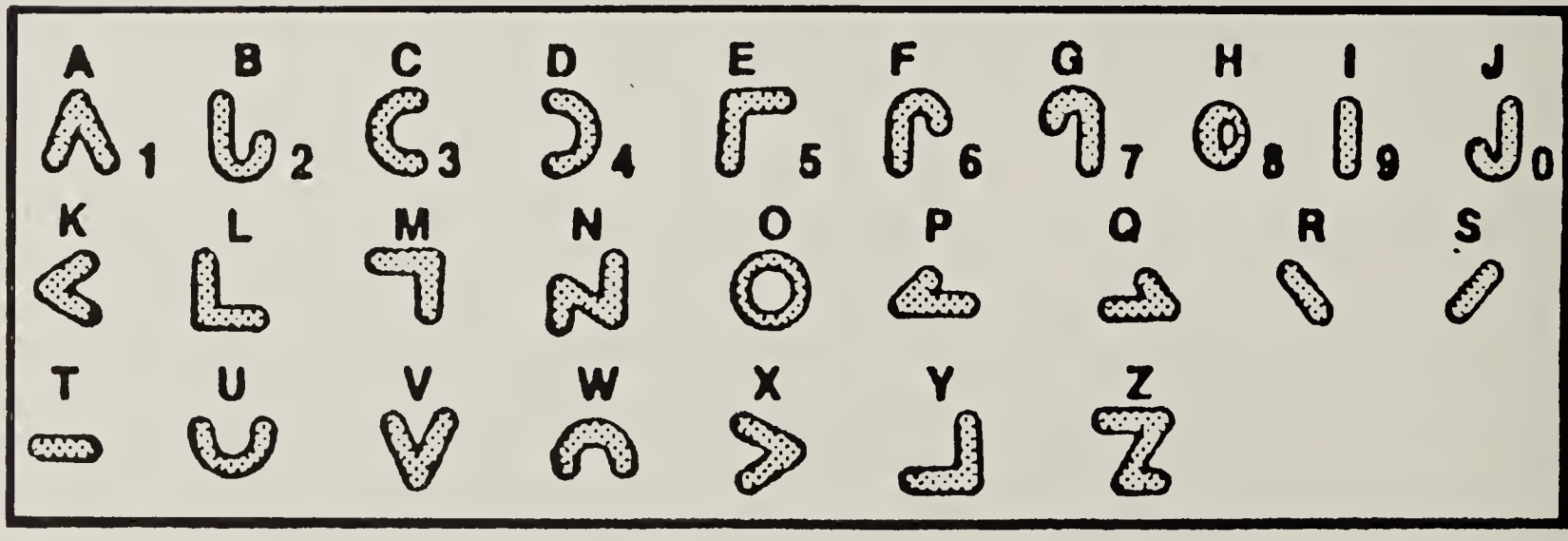
- Stereotype machines emboss braille characters onto double

metal sheets. These sheets are embossed on both sides. The metal plates are used in a press for embossing paper.

- Computer-controlled braille embossers emboss braille directly on paper.
- Vacuum-forming machines can be used for producing copies of single-sided braille masters. (The technique and machines are discussed in the section "The Vacuum-Forming Method," Chapter 2. For further information, see *International Survey of Aids for the Visually Disabled* (Gill, 1986), and for further references, see Appendix 4.)

MOON SCRIPT

Moon script is a system of embossed characters consisting of simplified letters of the inkprint alphabet, straight and hooked lines, angles, circles and half circles. It is a clear bold type for people whose touch is not good enough for reading braille—people with circulatory problems, elderly people, and those persons who have lost their sight later in life.



The alphabet in Moon script.

The alphabet contains nine characters. The meaning of these characters depends on the way they are used. The lines are read alternately from left to right, then from right to left, to make it easier for the reader to keep his or her place.

Moon print is produced at a section of RNIB in England. A portable writing machine has been developed to enable blind people to write their own material. This machine may result in the adaptation of Moon print to other languages. The machine is available from RNIB.

PICTURES WITHOUT WORDS

If the same master is to be used in several different books whose requirements are different, a display without words is often desirable. Also it encourages active participation by readers. Print extra sheets of braille text containing the names of various parts of the display (for a skeleton, these would be the names of the bones). The teacher would cut the braille labels from the sheet and the student would place them in the right areas of the display. Pliable adhesive plastic keeps the labels temporarily in place and ensures their easy removal.

An alternative would be a separate braille text on a page facing this wordless display. The text page would vary according to the grade level of the book for which it is used or the information to be imparted. If a picture is to be used in material produced in other countries, include a separate key that can be translated into other languages and fastened to the display.

ABC AND 1, 2, 3

Recognition of the inkprint relief letters and numbers that are prevalent in most communities—numbers on houses, apartments, and elevator floors as well as embossed names on doors, shops, and mail boxes—is a great help for visually impaired people. Persons with visual impairments can understand relief diagrams, even if they do not read braille.

Young children who learn the inkprint alphabet will be able to write their own names, addresses, and telephone numbers and will find it easier to use the Optacon machine, a direct inkprint reading aid for visually impaired persons. Older students may already be using the Optacon and can recognize a variety of printed styles. Two other groups of readers who may benefit from using inkprint letters and numbers are those who still have a memory of the inkprint alphabet and those who have some sight.

The size of the figures to be used is variable, depending on the age, ability, and background of the reader. It may be necessary to increase the scale of the diagram to accommodate inkprint figures that are easily recognizable.

Figures can be embossed by a spur wheel or a freehand drawing stylus. They can be formed in string or wire, cut out of cardboard, pressed into metal foil, printed in embossed letters

on tape by a large-print labeler, or made of heat-resistant plastic. Large-print labelers or embossing machines are available from the 3M Company.

Letters produced with a large-print labeler (*actual size*).

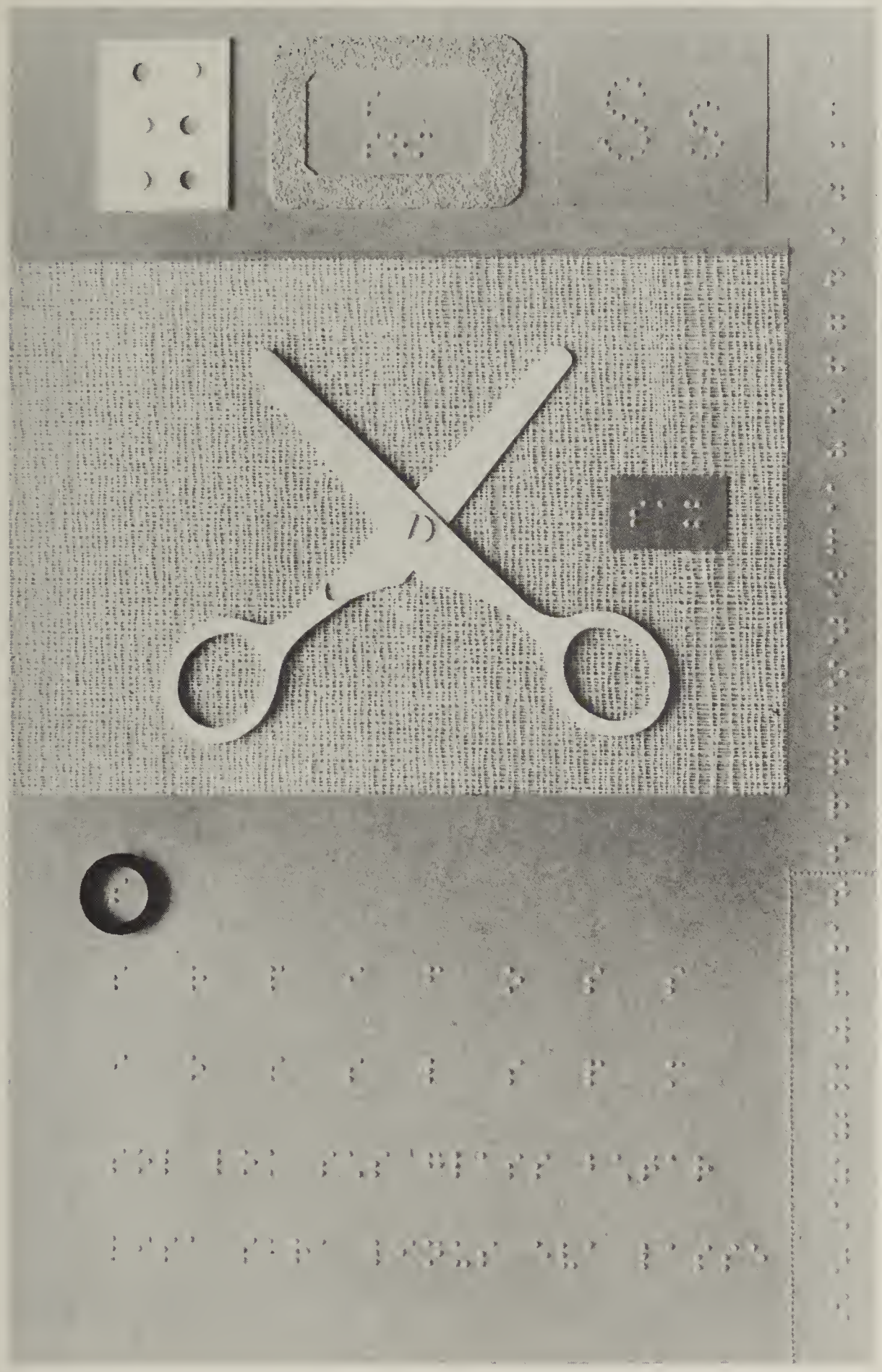
Many commercial letters and numbers made of paper, cork, or plastic are available at stationery stores, hobby shops, and advertising studios. Select very simple figures, and remember the following:

- If the display is to be mass-produced, be sure that the material in the figures can withstand the heat of the vacuum-forming machine.
- If the use of inkprint letters or numbers is new to the reader, it is advisable to accompany the display with a key explaining their use.
- The use of relief inkprint letters and numbers can enlarge the amount of available relief symbols and give readers added practice in reading this type of figure. However, because of their specific requirements, these figures are not often used.

ABC Books

Inkprint letters can be introduced to young readers by including one or two embossed inkprint letters per page in an ABC book with relief pictures and letters and words in braille. The child may not understand the inkprint letters as readily as the braille letters, but subconsciously he or she will become aware of their form (learning through association). The two alphabets presented together at this early stage may make it easier for the young person to learn to read with an Optacon machine.

The picture illustrating each letter of the alphabet should be a familiar object to the reader whenever possible. This will make object recognition easier for the reader. If possible, use these objects in context and present them in their actual size so that three-dimensional objects of a similar character can be used with these illustrations. This technique helps in the early training of picture perception (see "The Complete Object," this chapter).



Relief page from *Bokstavsboken*, a Swedish ABC book (Fellenius, Lindblad, & Edman, 1979).

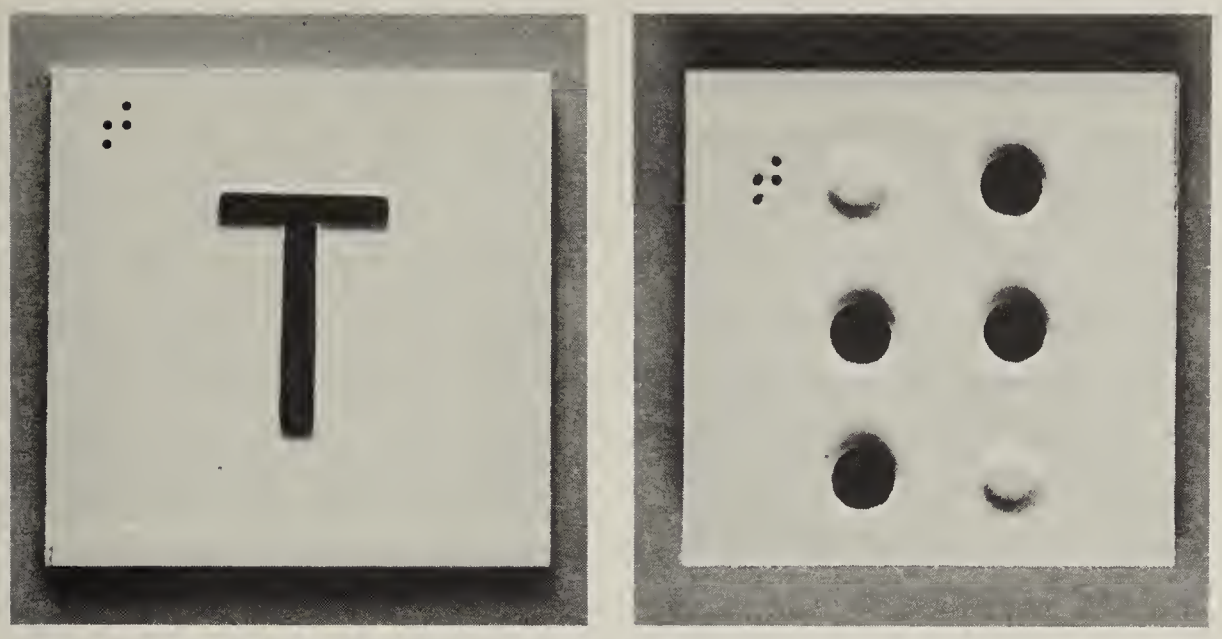
The relief page from a Swedish ABC book shown here includes the following elements:

1. An enlarged braille cell showing the letter *S*. This is a direct transition from playing to learning. The children had been using a six-hole egg carton and six small balls to learn the patterns of the braille characters.

2. A sandpaper frame encloses the letter *S*, in standard-braille size, and the word "som," which means "that" in Swedish. Sweden was using abbreviated braille when this book was made. "Som" was designated by an *S*.
3. A capital and a lowercase *S*, as they would feel to a reader using an Optacon machine. A small child is not expected to recognize or understand this part of the page. It is presented to awaken the child's curiosity and perhaps to play a part in subconscious learning.
4. The name of the illustrated object, "sax," or "scissors."
5. The letter *S* within a rubber washer. The area around the *S* is large enough for a small finger to move over the letter and feel the dots that form the *S* (captive comprehension). The shape of the rubber washer was changed in a 1989 revision of this material to an oval shape that allows the reader more finger movement in the confined area. The oval is made of leather, the same thickness as an outline of the washer but a little wider in shape.
6. Two rows of braille letters that could be confused with *S*. Several *S*s are included among these letters.
7. Two rows of words containing *S*.
8. The alphabet from *A* through *X, Y, Z,* to *Ö*. The letters are placed under each other in a line along the outer edge of the page.
9. An embossed line starting just under the *S* makes a right-angle turn and goes to the bottom of the page. The teacher will cut away this area within the embossed lines and the edge of the page when the child understands the content of the page and easily recognizes the letter *S*. This book will eventually have a complete finger index when the child becomes proficient with each page. The alphabetical index can also be used for looking up the meaning of an abbreviated word (*S* meaning "som") or the inkprint version of a braille character.

ABC Cards

ABC cards consist of two sets of small cards (they are shown on the next page in actual size), one set containing a series of large, uppercase relief letters or numbers and the other containing the braille symbol for each uppercase letter or number. The braille character is made with large raised dots. The same



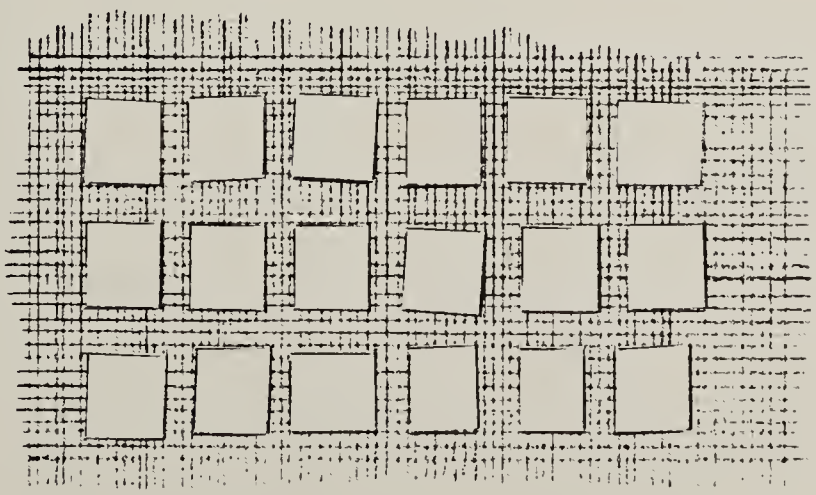
ABC cards (*actual size*).

braille character is repeated in the upper left-hand corner in a standard-size braille cell.

The cards are made of cardboard. The unfilled holes of the braille cell can be made with a hand-punch. The raised dots, the same dimension as the unfilled holes, can be punched out of a similar piece of cardboard and glued onto the background.

Flannel can be mounted on the back of the cards to keep them from slipping away when they are being used to form words. For best results, the reader can work with his or her cards on a flannel board.

If these cards are to be mass-produced in a vacuum-forming machine, place several of them together on a single sheet of backing material to utilize the size of the plastic most economically. Embroidery canvas works well as a backing material; it will allow air to pass through hundreds of tiny holes between the cards, thus ensuring a sharp plastic copy.



Cards mounted on embroidery canvas backing to facilitate mass production.

These cards can also be reproduced on microcapsule paper. They are excellent for games; the black print of the

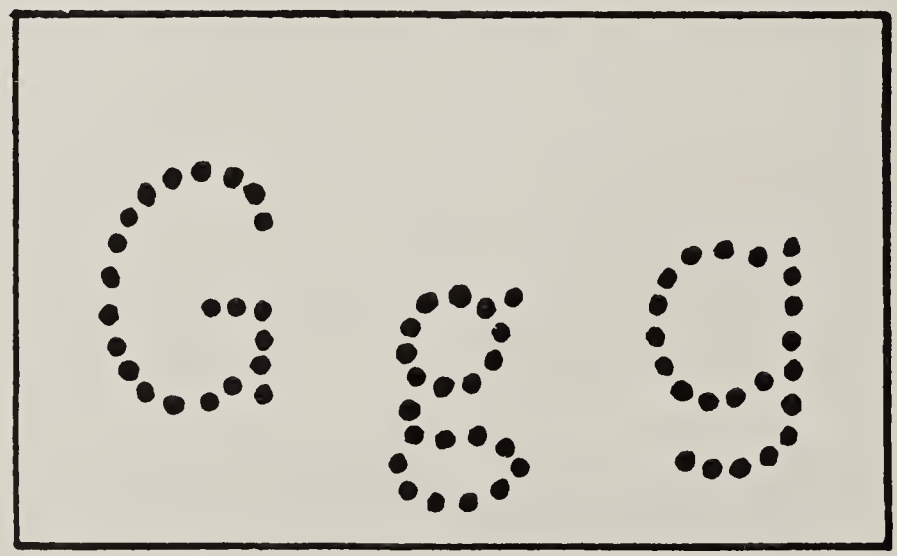
microcapsule process makes it possible for blind children to play cards with their sighted and low vision friends.

Here is one suggestion for a game: Deal a certain number of cards, and place the remaining cards in a pile between the players. The players then draw and discard cards as in most games of rummy. The person who is able to collect the greatest number of pairs—one braille and one print card of the same letter—wins the game.

Mount these microcapsule cards on cardboard to increase their stability and also to make it more difficult for the players to guess their opponents' cards by the dark forms or relief areas that may show through from the back of the paper.

ABC for Optacon Readers

For Optacon readers, uppercase and lowercase inkprint letters are shown in relief with their braille counterparts. Figures made with a spur wheel or a freehand drawing stylus may give more of an impression of the figures produced by the Optacon machine than a smooth-line figure. If there are two distinctly different figures in use in the lowercase version of a letter, it is advisable to show both forms, as in the example below.



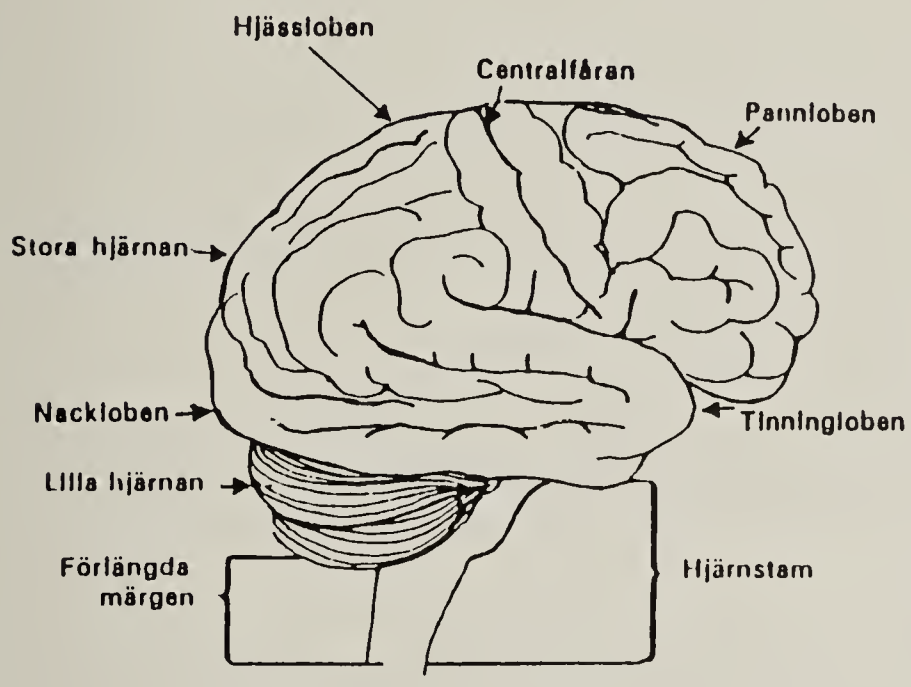
Letters produced for Optacon readers.

ARROWS

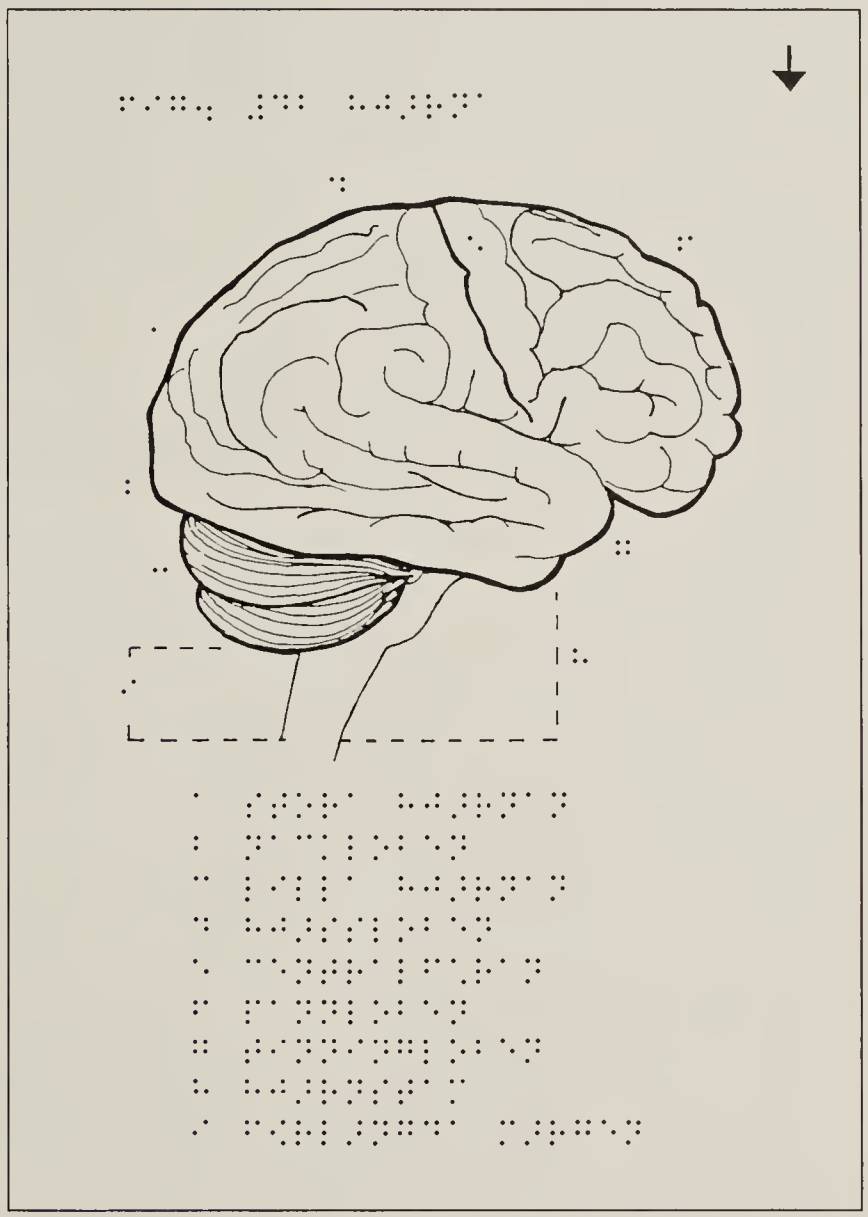
If an arrow is to fulfill its function, it must be felt! Some blind students find that they may lose the purpose of the arrow between the time they start to trace the shaft of the arrow and the time they arrive at the head of the arrow. Why was the arrow there? What was its relationship with the other components of the display?

The following suggestions clarify the use of arrows:

- Restrict the use of arrows in a display. Arrows are frequently used in inkprint to connect information to a particular area. When a diagram is enlarged in preparation for becoming a relief display, it may be possible to insert a letter or a number into a particular area to eliminate the need for an arrow. A key is often a better solution than arrows and may help make the display less congested, as in the example shown here.



This Swedish textbook illustration of the brain uses arrows, and its tactile graphic display, made on microcapsule paper, substitutes a key.

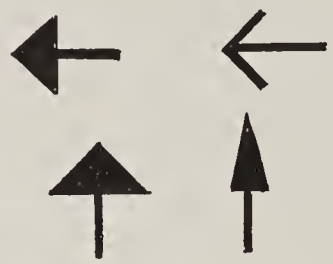


- Arrows should be well defined; they may become an integral part of the picture if they are not. There are many ways to make an arrow. Your choice depends on your method of production and the design of the display.

  The head of an arrow should have a wide base, the angles acute, and the point a 90 degree angle. With this shape, the head signals a definite change to the fingers as they travel the length of the shaft and indicates the direction of an immediate point of interest.

The narrow base of some inkprint arrows should not be duplicated in relief, because there will be no definite difference in feeling between the head and the shaft, resulting in some question about the direction of the arrow—or whether or not it is an arrow.

Some types of arrows are shown below:

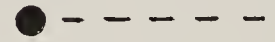


A solid arrowhead is preferable to an open one.

The wide base, as opposed to the narrow base arrowhead.

Three dots made with a freehand drawing stylus; the shaft is made with a spur wheel.

A string or thread is used in place of the embossed line.



A jumbo dot made with a freehand drawing stylus or a dot punched out of cardboard and an embossed shaft.

A cardboard arrowhead with a string or embossed shaft.

A knot arrowhead on a string/thread shaft. Leave a short end after the knot for a better gluing surface.

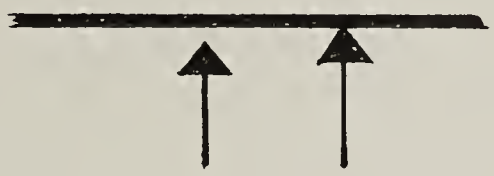
A directional arrow—excellent on microcapsule paper. It can also be embossed on braille paper by using the end of a screwdriver and a dot with a correction tong.

- The size of an arrow depends on the display and the importance of the arrow. Some displays require several different-size arrows. A small arrow is understandable if it is distinct.

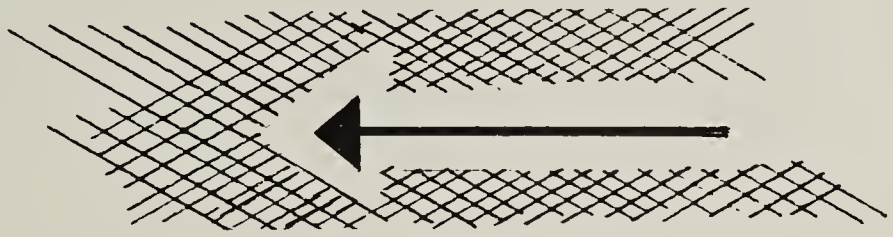
  Again, be restrictive. Do not create a cluttered area. If there is too much information in one display, break the

design down into a step-by-step presentation (see "Simplicity," this chapter).

- Keep a distance between the arrowhead and its designated point. Do not have them melt into each other.



- Placing an arrow in a textured area is not advisable. However, if it is necessary to do so, give the arrow enough free space around it so that it will not be lost in the surrounding texture (a minimum of about 1/8 in. [3 mm]).



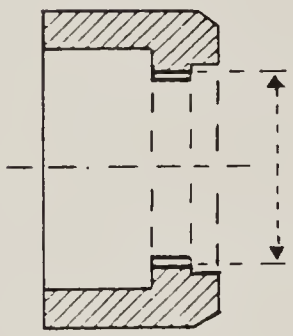
This is especially important in reliefs of one or two elevations. It is less important in displays built up of many layers and least important in tactile-experience pictures.

- A complete arrow (see A), unbroken by intervening information or lines, is easier for the reader to follow than a divided arrow (see B).

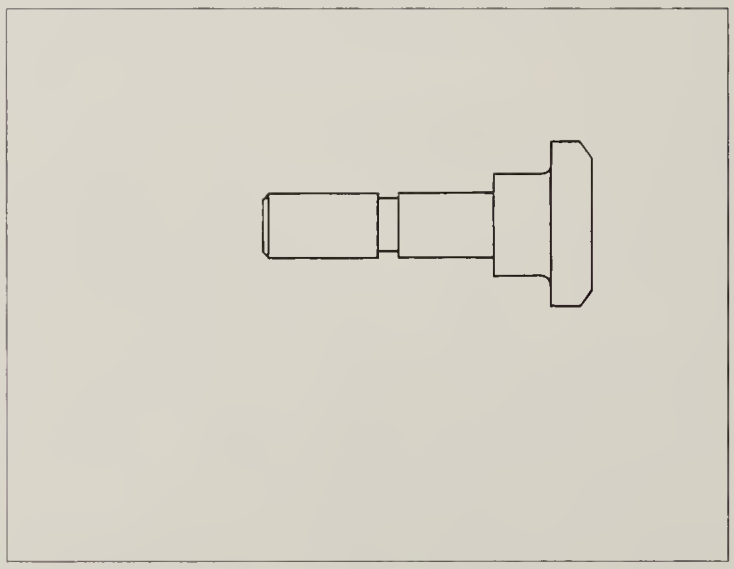
An arrow should have right-of-way if it is so important that it crosses a line in a one-elevation display or in an embossed or microcapsule paper display. Leave a blank space between the line and the shaft of the arrow.

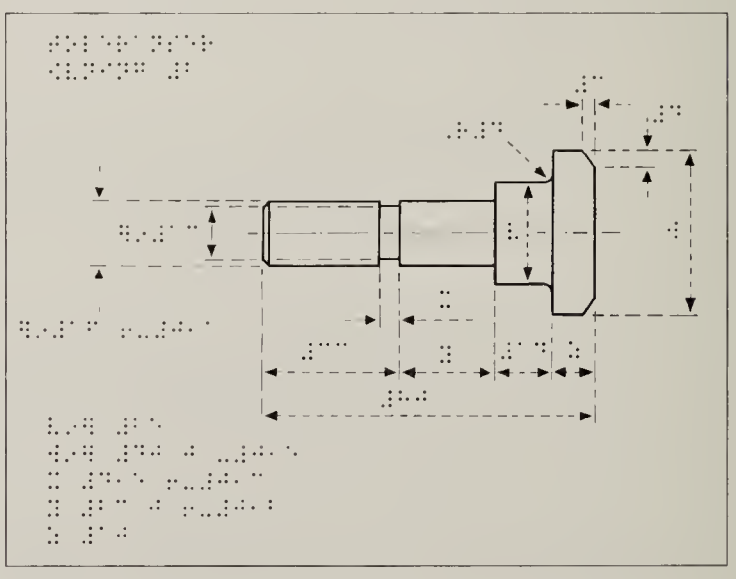
If it is necessary to divide the shaft of the arrow into two or more lengths, put an arrowhead on each one of the lengths.

- A dotted or dashed arrow shaft is desirable if the arrow is not an integral part of the form or display—if it is only a bearer of information or a connecting link between two points, for example.



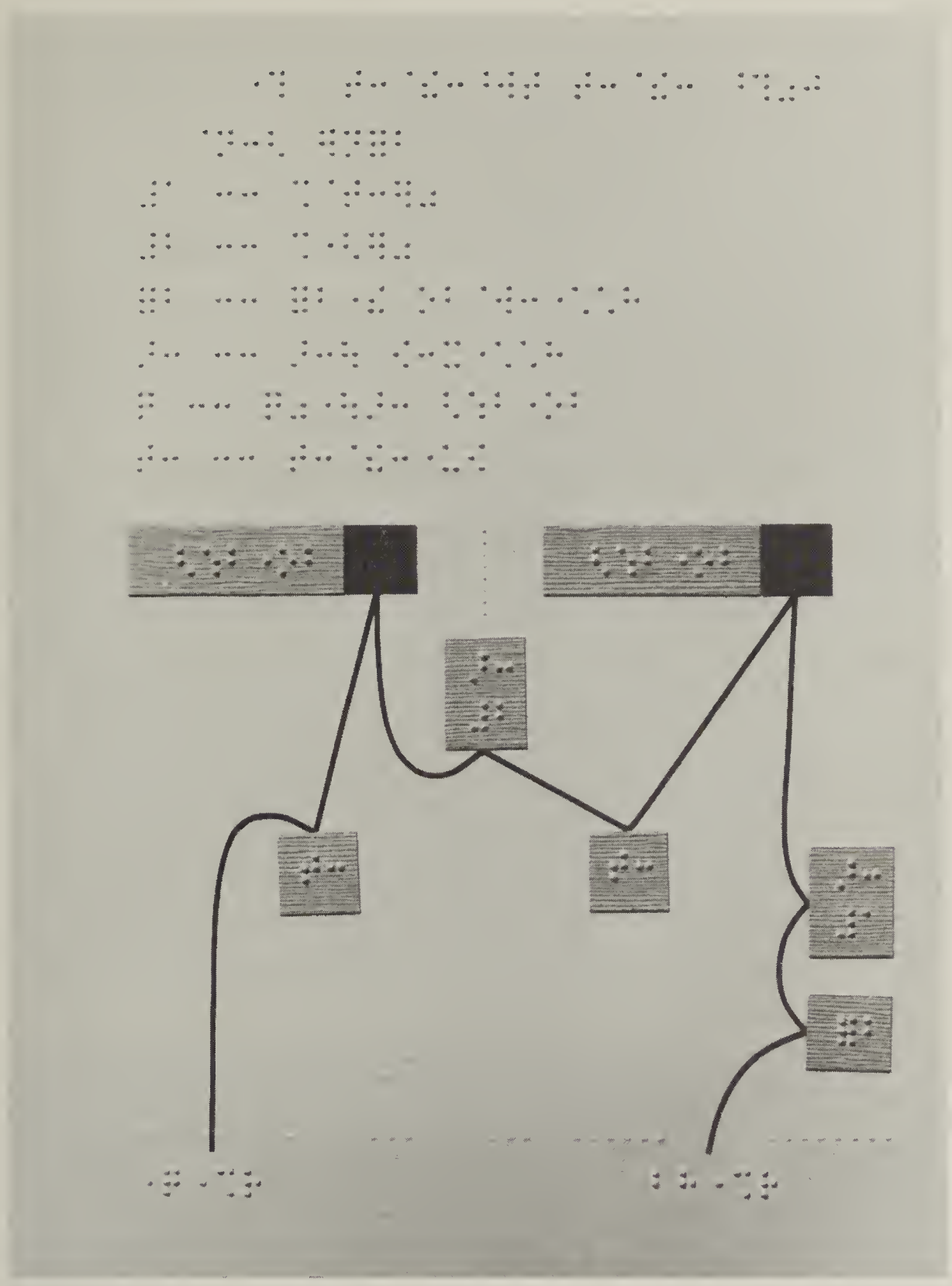
- A single dotted line connecting information with a particular point in the display is often used in place of an arrow or in connecting arrowheads. When using this technique, be sure that the dotted line cannot be misunderstood to be part of the actual form or map. The dots should be fine enough to differentiate them from other dotted or dashed lines in the display. It is advisable to avoid this technique if similar dotted lines already exist.
- If too many arrows lead into a display, it may be necessary to show the picture first without any arrows so that the reader can understand the basic forms in the display. Then, present the same display with the addition of arrows and information, as shown below. This technique is a version of the step-by-step technique.



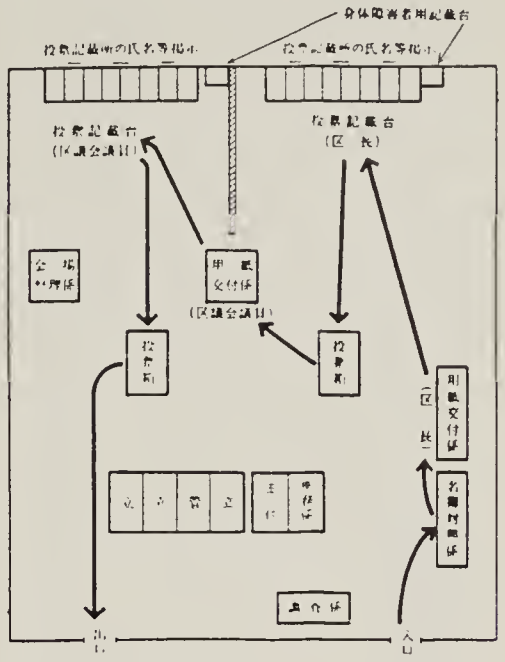


Material illustrating a problem relating to the production of machine parts, produced on microcapsule paper, with arrows added.

- Too many arrows can clutter a diagram. A Japanese solution to presenting the flow of information in a diagram is a solid raised line, which can be seen in the tactile display shown on the next page along with the drawing on which it is based.



This relief master is based on the drawing shown below, which appears in *The First Step to Tactual Graphics for Braille Writing*, published in Japanese by the Japan Braille Library, 1986.

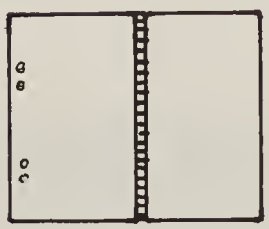


The Reading-Direction Arrow

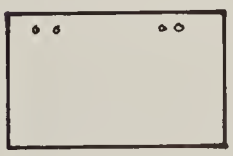
Many of the displays in braille books are too large to be placed on a perpendicular page (see A), but not large enough to necessitate a foldout page (see B). Consequently they are made to fit a horizontal page as opposed to a vertical page (see C).

If the forms of a display are read upside down or sideways, they may lose their original meaning and become entirely different forms to the blind reader. An arrow in the upper right-hand corner of the page will help to eliminate this problem.

A.

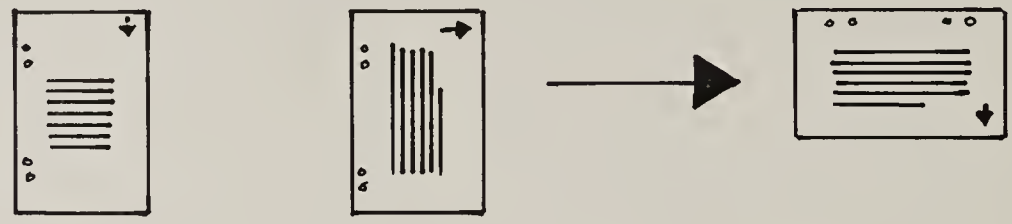


B.



C.

The arrow points toward the reader when the display is in the correct reading position. This system can be used on both bound and unbound material.

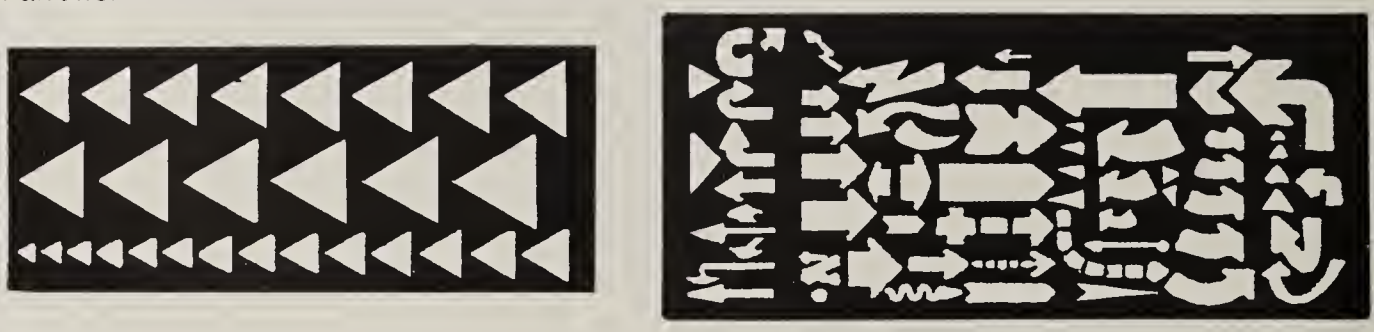


These arrows have been effective with students. However, it is important that information concerning the use of these arrows is printed at the beginning of each braille book in which they appear; otherwise they will be meaningless.

The reading arrow should be the same size and shape on all types of relief material. Horizontal or vertical, it is always the same. Once you have established a size that is acceptable to your readers, make a stencil for making the arrows.

A stencil is a device for applying a design or character to a surface. It consists of a thin sheet of plastic, cardboard, or metal in which the design or characters have been cut so that ink or pencil lines can be traced through the incisions onto the surface below. Many types of stencils are available at paper and art supply stores.

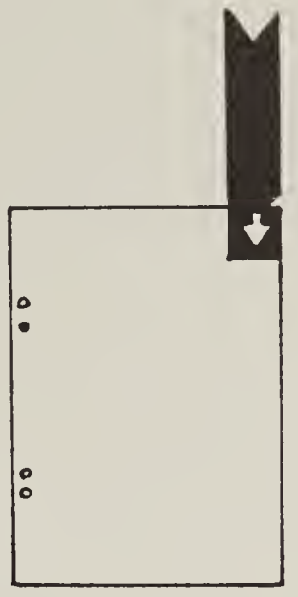
Sample stencils used for making a variety of arrows.



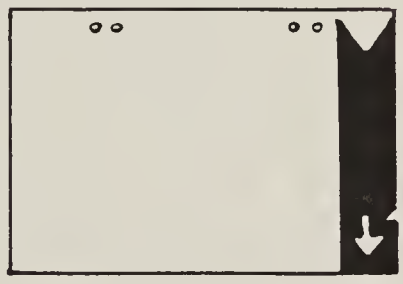
I have made my own stencil from a piece of thin plastic—.01 in. (.25 mm). The arrow was cut out with a scalpel. This is the actual size:

The stencil is made so that the distance between the arrow and the corner of the paper is always the same. The notch cut into the edge of the stencil regulates this distance on a vertical display (see A). The distance of the arrow from the end of the plastic stencil regulates this on a horizontal display (see B).

I use a pencil to draw the outline of the arrow on a surface material. The arrow may then be cut out with a knife, embossed with a spur wheel, or filled in with black ink for a microcapsule paper display.



A.



B.

The Directional or Tactile Arrow

Many blind students seem to have difficulty understanding that arrows are a symbol indicating direction. Therefore, a tactile symbol has been created that has the structural property of directionality built into it rather than being arbitrarily assigned to it, as is the case with the visual arrow symbol.

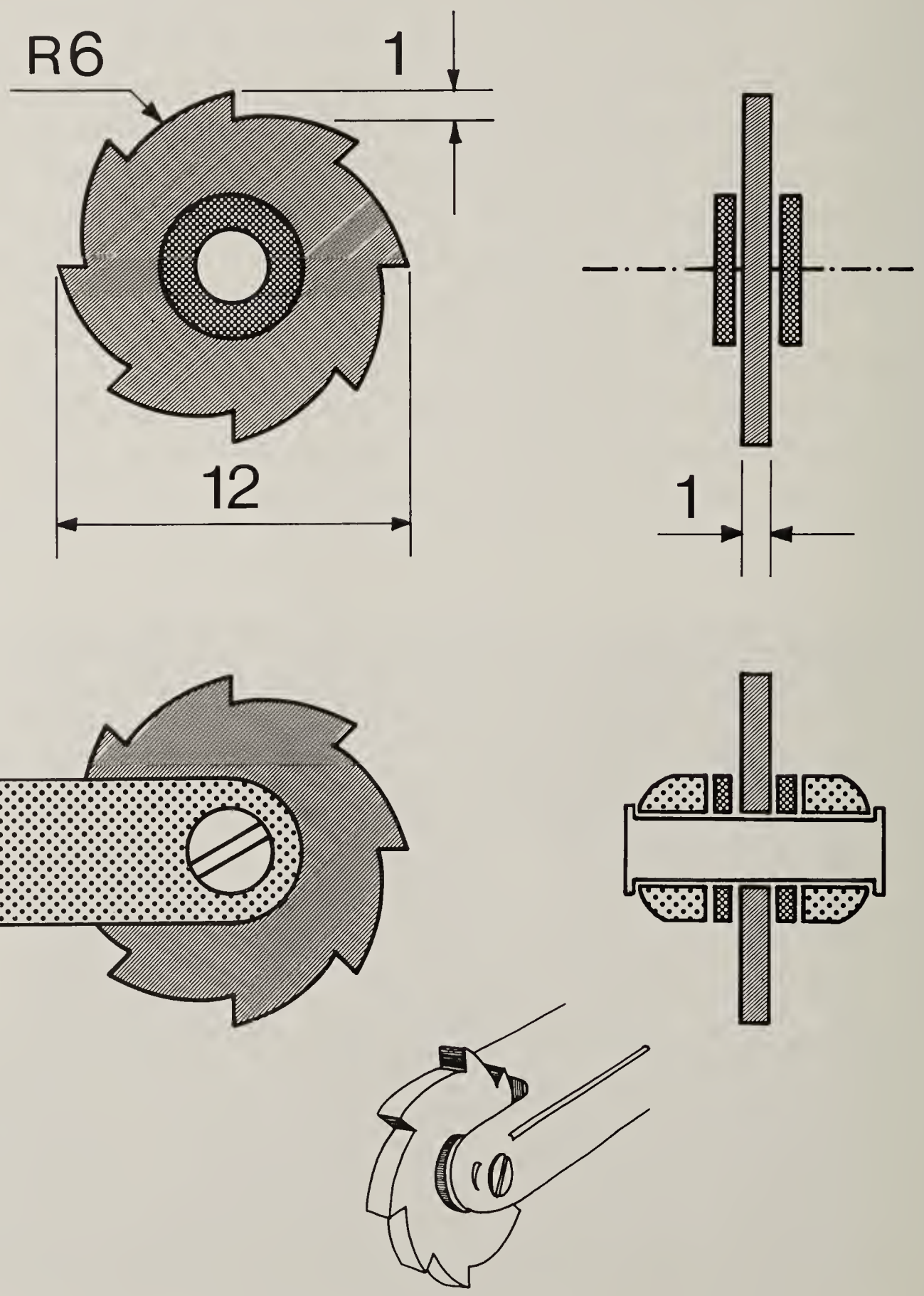
The directional arrow is made with a special instrument that imprints a sawtooth pattern into metal foil or paper when it is rolled across the surface. This pattern feels bumpy-smooth when a finger strokes it in the intended direction in which it is pointing. When stroked in the opposite direction, the line feels rough, sharp-bumpy. The advantage of this symbol is that it

Imprinting a sawtooth pattern for a directional arrow.

An enlarged cross section of the relief made by the directional arrow.

forces the fingers to continue in the right direction. The reader can feel the direction of the arrow anywhere along the "arrow line" (see Schiff, Kaufer, & Mosak, 1966).

Unfortunately the directional arrow instrument is not, at present, sold commercially. William Schiff, the inventor of the instrument, has given his permission for the use of the working drawings shown here to all who wish to produce their own instruments.



Enlarged working drawings for Schiff's instrument for the production of directional arrows. R = radius. (Drawings by Robin Edman, SID).

PEOPLE

Detailed suggestions for creating figures of people are found in the section "Tactile-Experience Pictures" in Chapter 2. Here are some additional suggestions:

- Try to show both arms with hands and both legs with feet.
- Hair on a figure is easier to understand if it follows the shape of the head and is not influenced by a visual impression (unless otherwise stated in the text).

Young readers often mistake braids for an extra pair of arms. To avoid this problem, use real hair, so that the texture tells the child that it is hair. If braids are necessary in a microcapsule illustration, be sure to explain their existence in the braille text accompanying the illustration.

- Heads are generally so small that it is necessary to keep mouths simple. A thin string or embossed line will suffice. A mouth as a deep-cut slit is only understandable on a relatively large-scale figure.
- Fingers and toes can be cut from leather or cork to avoid splitting, as so often happens when small bits of cardboard are used.

ANIMALS

Several principles are important to follow when depicting animals:

- Try to show all legs, including feet, paws, or claws. Animals in printed pictures often have two legs so close together that they become one thick leg. If the animal is transposed into a relief display in this position, it could be confusing. The animal becomes a three- or two-legged creature, even if the height between the legs is well marked.
- Check the position of the tail. Is it characteristic for that animal? A mouse, for example, does not carry its tail high

over its back or hanging below its body. Both positions feel peculiar to the reader and belong to visual pictures. Depending on how it is placed, the tail of a gamboling lamb could be perceived as a fifth leg unless there is a marked difference between the shape and placement of the tail and the legs.

All four legs of the camel are plainly visible in this paper-on-paper buildup.

This lamb, in a tactile-experience illustration, was probably copied from a printed picture. Because of the shape and position of its tail and legs, it is completely confusing to a blind reader. A reference line could also help alleviate confusion.

- Distinguish the ears from the horns. Otherwise, some animals that do not really have them may end up with horns. It is more understandable to young readers to feel two ears, even if the animal is shown in profile. However, this may not be possible if they are very small. Ears are easier to read if *both* of them point in the same direction—up, down, forward, or backward, as opposed to one up and one down, as is often seen in inkprint pictures.

ARCHITECTURE

As with other kinds of figures, making architectural structures part of a tangible display calls for some special considerations. Here are some suggestions to follow:

- Perspective is a visual phenomenon. Do not use it in an architectural display unless there is a valid reason for doing so, such as an explanation of sight or perspective.
- Buildings and houses should be placed on a reference line (see "Reference Lines," this chapter).
- Simplify buildings and houses. Do not put too many windows, or too much detail into the display (see A below). Do not make the buildings so small that they are difficult to understand.
- Peaked roofs seem to be more readily recognizable than flat roofs (see B), probably because of the reader's familiarity with three-dimensional models. However, both types of roof are acceptable.
- Try to keep a definite size relationship between buildings or houses and people, trees, animals, cars, and other objects that appear in the same display.

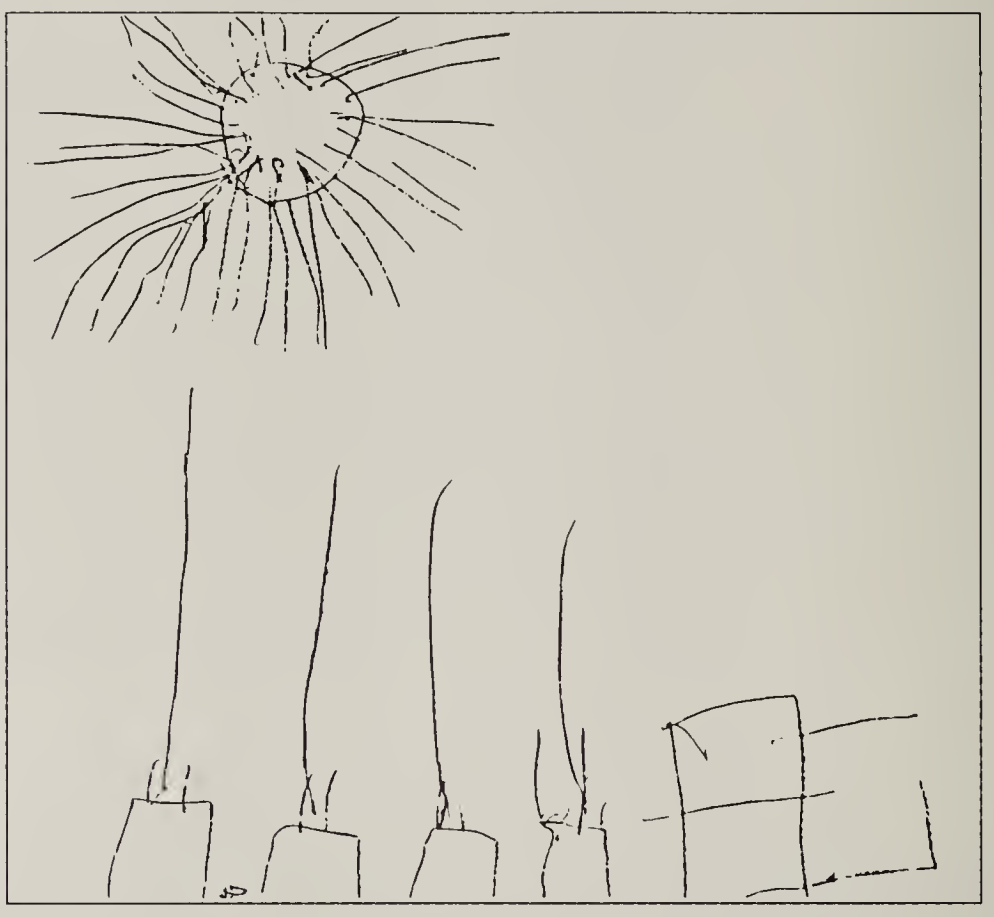
A. In this tactile-experience picture, the little house is made of balsa wood. The roof is plastic. The chimney and foundation are sandpaper. The door will also open.

B. In this tactile-experience picture, the bakery is made of thin pine wood. Much to children's delight, the door opens. The bakery goods in the window are there for the low vision reader. The window is clear plastic. The plastic lettering over the door was an experiment that worked; the children who used this book could read the letters.

A.

B.

- Trees, shrubs, fences, and other elements in the picture should not be placed so close to the building or house that they become an integral part of the architectural form and confuse the reader.
- Chimneys can be left open at the top if they appear in an embossed display. This is often the way blind children draw them, as in the picture of the sun and chimneys shown here.



In this raised-line drawing by a 9-year-old boy, the smoke is rising straight up through open chimneys.

Bricked area with air holes to ensure efficient vacuum forming.

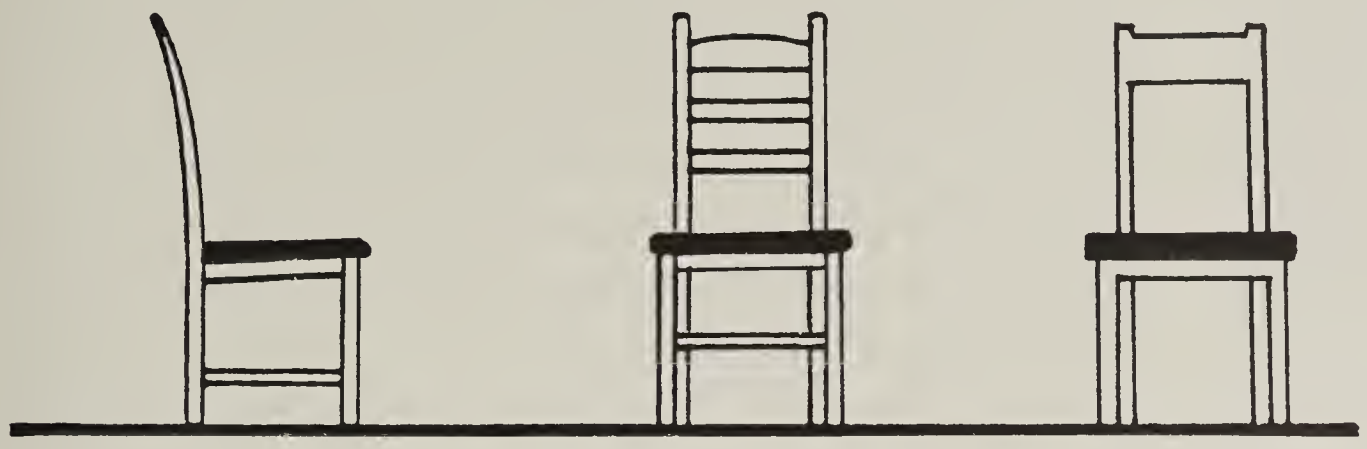
- Building bricks or stones in a layered relief should be made out of material that will not split or peel off when plastic copies are made. Leather, thin metal, veneer, sandpaper, or heat-resistant plastic can be used. Put air holes in the bricked area to allow the vacuum process to function properly. This will produce a well-defined area in the plastic copy.

FURNITURE

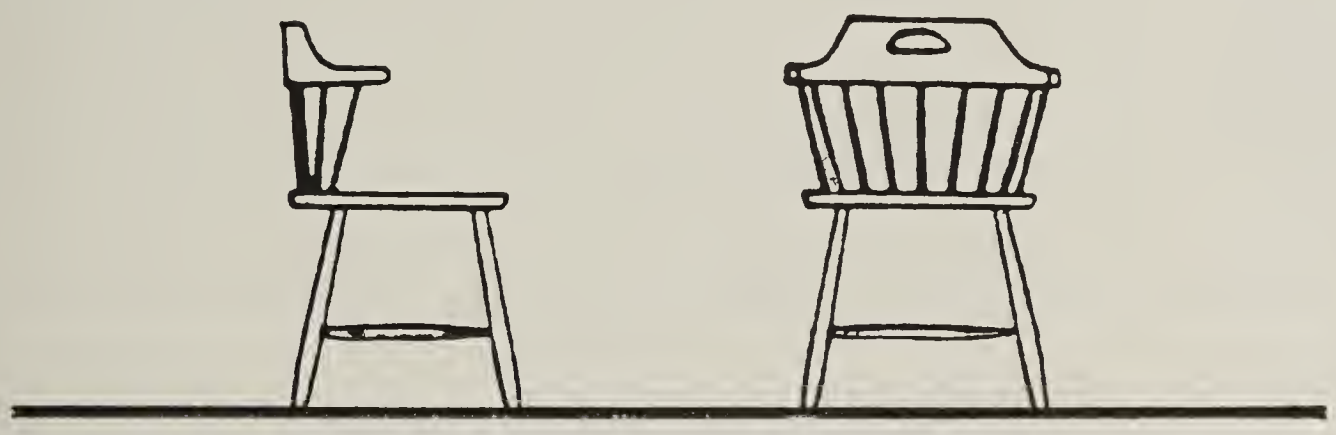
Furniture forms can be confusing to blind readers if they are not clearly and simply rendered. In addition, these principles should be followed:

- Choose forms that the blind reader is familiar with, unless otherwise stated in the text. Make them simple. Portray them in profile or full-front view.

This chair form is easier to understand



than this form.



- Furniture should be placed on a floor line. A reference line will give the reader more information about the object and its relation to any other figure or object.
- Try to keep a natural size relationship between furniture and any other object in the display, unless otherwise described in the text. Illustrations for children's stories such as "Goldilocks and the Three Bears," where the furniture is of various sizes, are exceptions. Other exceptions would be oversized furniture, as a child experiences it, and undersized furniture, as it would feel to a giant.

This chair was drawn by a young blind child.

TREES

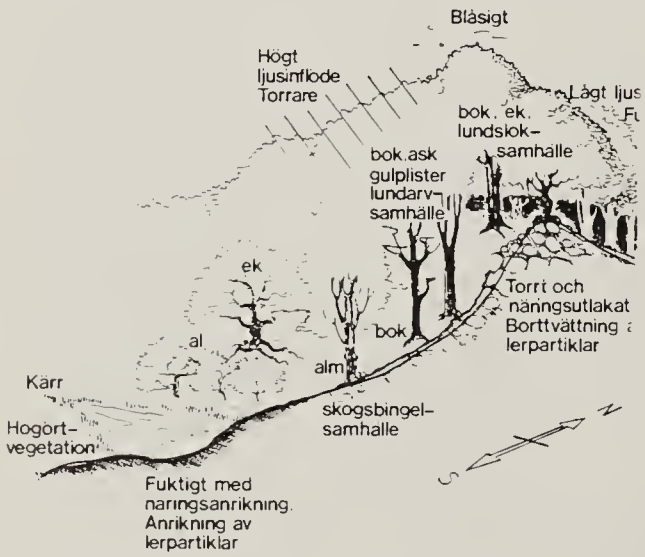
A tree is something blind readers have difficulty visualizing. They can touch the tree trunk and feel a small tree, but they find it difficult to understand the tremendous height of a pine tree, the magnitude of an oak, or the unusual shape of a palm tree. Therefore, it may be helpful to portray a tree, along with a form such as a person or a house, to give readers an idea of size relationship.

- Trees should stand on the ground, on a line. They should not be free-floating forms.

- Keep their form simple but do not make them look like clouds on a stick. Branches are as important to a tree as arms and legs are to a person—show them. Children have told me that they like to feel the branches.
- If several characteristic tree shapes are being compared, be sure that the trees are presented in the same scale. (Tree forms do not have to be varied if several trees appear in the same display, unless this is part of the desired information. Repetition is fine and causes less confusion for the reader.)

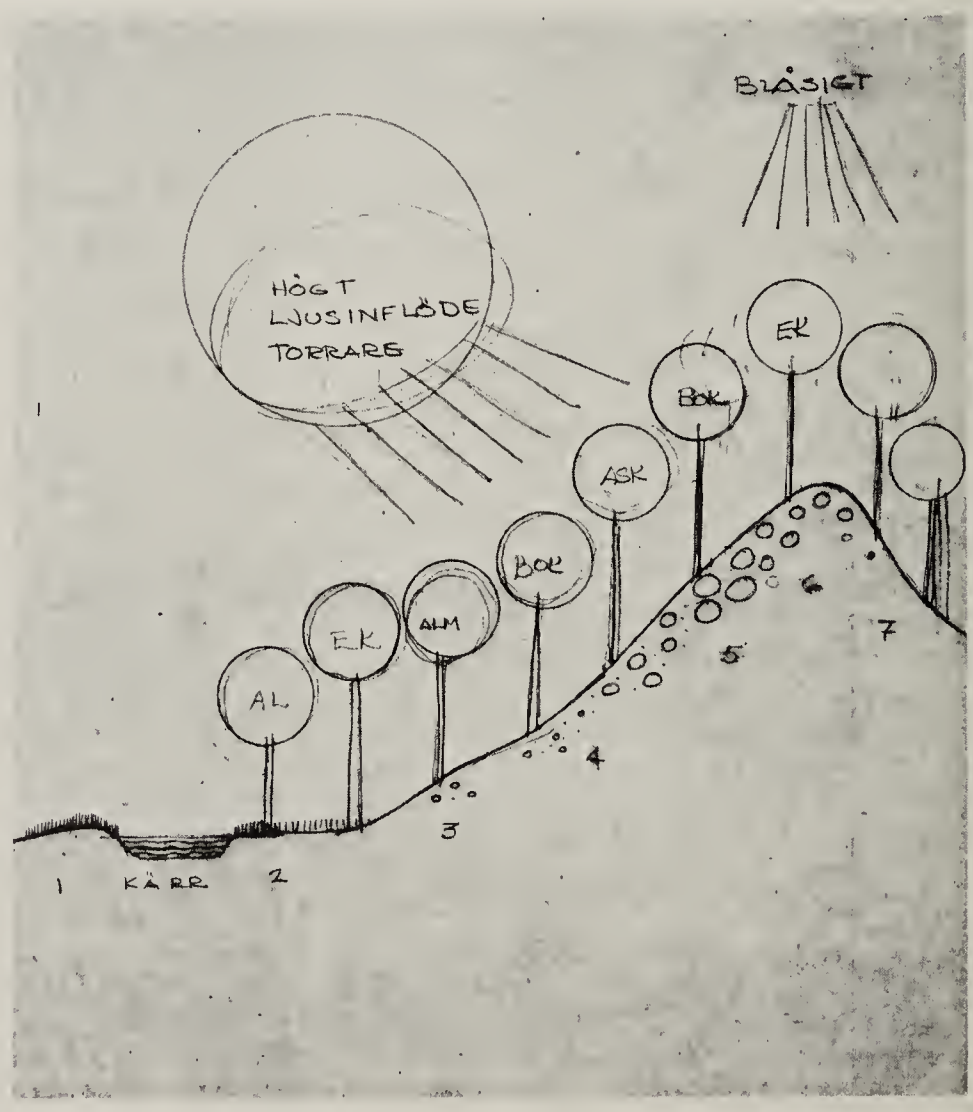
Trees with branches.

In the following display, the tree becomes a stylized symbol on which to print names. The important information here was not the form of the tree itself but the location of a



ABOVE: The original textbook page. The important point of the picture is the location of the particular types of trees in relation to the area in which they grow—damp, dry, clay, and so on.

RIGHT: The sketch for the master. In this rendering of symbolic trees, each type is named. A key was used to describe the growing areas numbered 1 to 7.



particular tree in a particular area. The size of the display and the number of trees required a simple solution.

Keep an open mind to the feel of things. In spite of the fact that the trees in a tactile-experience book were made of plastic parsley and could be identified as parsley by a sighted person, to the blind child, they were trees. Children enjoyed running their fingers through the leaves.

Trees made with plastic parsley.

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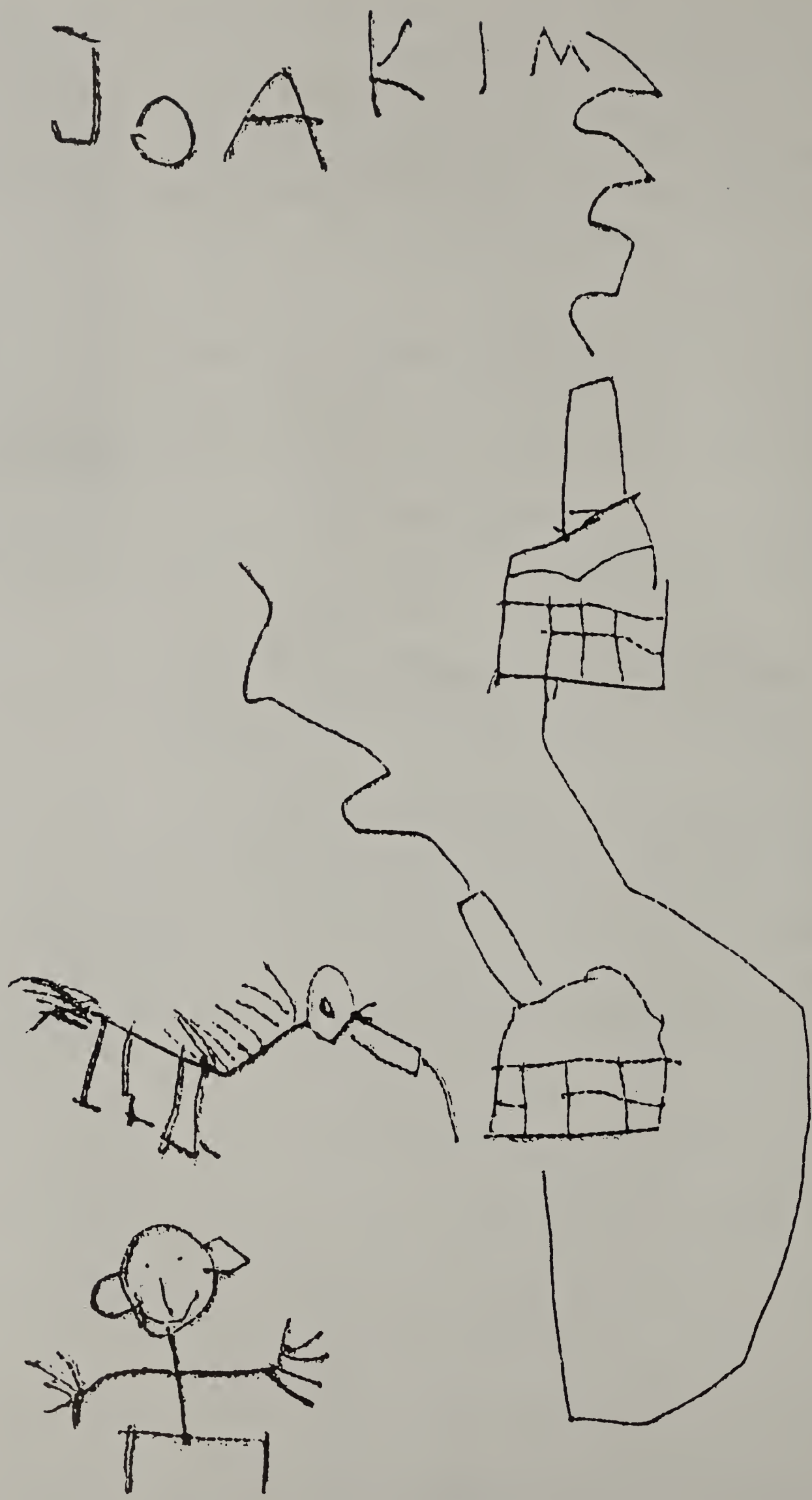

JOAKIM

CHAPTER 5

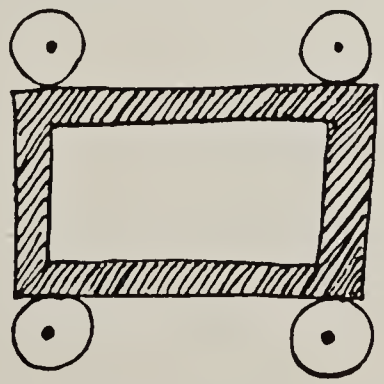
Children's Drawings: What They Can Teach Us

Drawing is not limited to those who can see. Blind children can also draw, and their drawings are completely understandable to you, to me, and to their visually impaired friends. It has taken a long time for this fact to be known. Not until a satisfactory drawing board was developed (see "Raised-Line Drawing Boards," Chapter 2) were these children easily able to use their inherent skills.

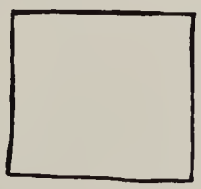
In 1959, after an accident that left me blind for several months, I began making relief pictures for blind children. The ensuing reaction of sighted adults, both parents and teachers, to my work was most unexpected. They said that children could not understand them—that the pictures would only lead to confusion and frustration. The children had another opinion: More pictures, more pictures!

OPPOSITE PAGE: Joakim, a 9-year-old boy blind after his first year, drew this picture showing a happy house and a sad house, a horse, and a man.

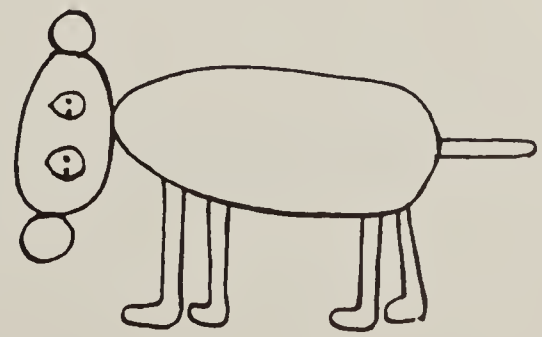
The opinion of a teacher in Kobe, Japan, is a good example of one type of opposition that I met. That teacher created the following pictures and insisted that blind children can understand a car only if it is portrayed this way:



or a chair in this form:



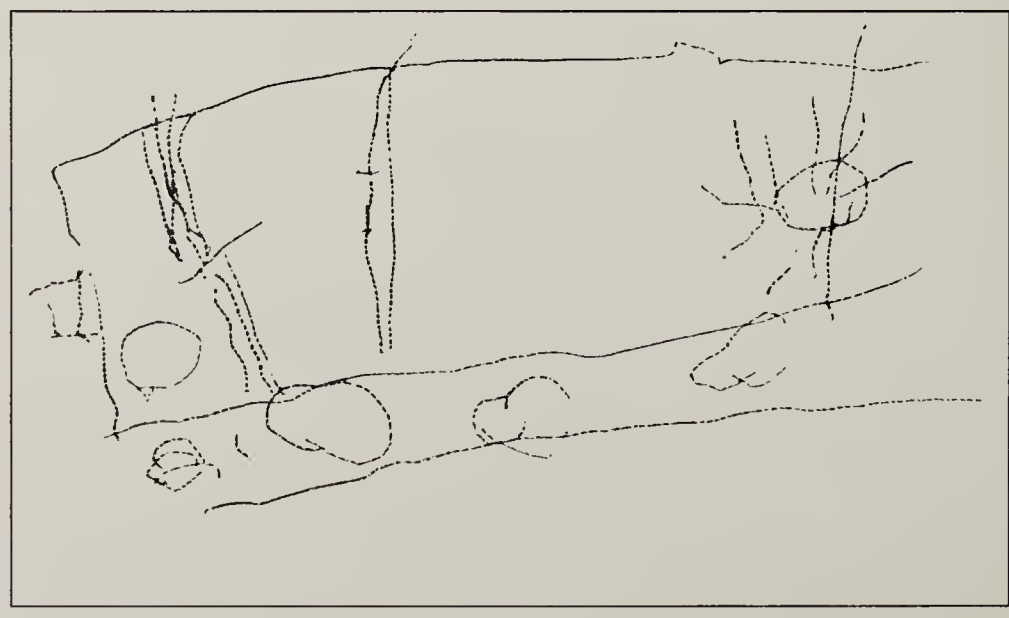
or a dog like this:



His thinking is understandable. A toy car is primarily seen and felt from above as the child rolls it across the floor. A chair is known by its seat—a familiar point of contact on which the child sits. I am not sure that I follow his line of thought concerning the dog picture. I do not think that his opinion is based on a cultural perspective. I believe it to be his own personal evaluation. I later had the opportunity to test these pictures of his with the children at Tomteboda School for the Visually Handicapped in Stockholm, Sweden. The children's reaction was confusion. What did these forms mean? My own pictures had been based on the theory that everyone must learn to "see" things. Seeing objects is a process that is acquired; it is not a trait that is fully developed at birth. We learn from the things around us. I felt that making pictures of cars and chairs as the Japanese teacher had shown would be to develop a language of separate symbols for these children. Was this really the way it should be done?

I decided that I must learn from the children themselves. The logical way would be to teach them to draw. From their drawings, I could learn how to produce material that might be easier for them to understand. The vast number of drawings produced by these children has shown me that they draw animals, people, and objects that are very similar to those drawn by their sighted friends.

There is, however, one noticeable exception. Some blind children may change visual planes within the same drawing, from a profile view to an overhead view. This change is normal, since these visual planes have little meaning to them; they are a sight-related phenomenon. The drawing of a truck by a 10-year-old boy, shown below, is an example. The boy began his



A drawing of a truck that began as a rectangle.

drawing with a rectangle. He then added stairs at the front of the truck, a steering wheel, a gearshift and front seat, and a back seat. He then added the sunlike form at the back of the truck. "Motor?" I asked him. "Not at all!" was his reply. "It's the decoration on the side of the truck." He hastily drew four wheels and a line that he said was the street. He had just switched surface planes, from an overhead to a profile view.

CHILDREN'S FEELINGS AND PERCEPTIONS

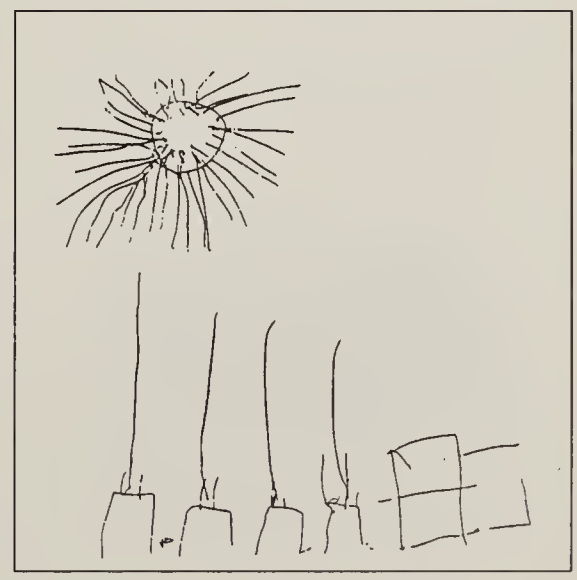
For years I have said that relief pictures made for blind and visually impaired people are basically a recording of facts. The feelings that can be conveyed with color or by expressions and actions in pictures for sighted people are limited or nonexistent in pictures for blind people. Yet examine the series of three drawings shown below (see A, B, and C) made by a 9-year-old boy who was blinded when he was 2 years old. In the first picture (A), a quiet sun is setting behind the trees. The second sun (B) is intensely hot. It pulsates with heat as it shines on the horse and cart and driver that are leaving a house. Note the faces in both suns. The sun is important to this young boy from Ethiopia, and it is definitely personal. The third sun (C) is a cool sun on a cool day. Smoke is rising from the chimneys. Are sighted children more aware of the changing aspects of the sun than the boy who drew these pictures?

Look again at those smoking chimneys—they are open! There is no line across the top of them, as is often seen in the drawings of sighted children. An open form is open, not closed!

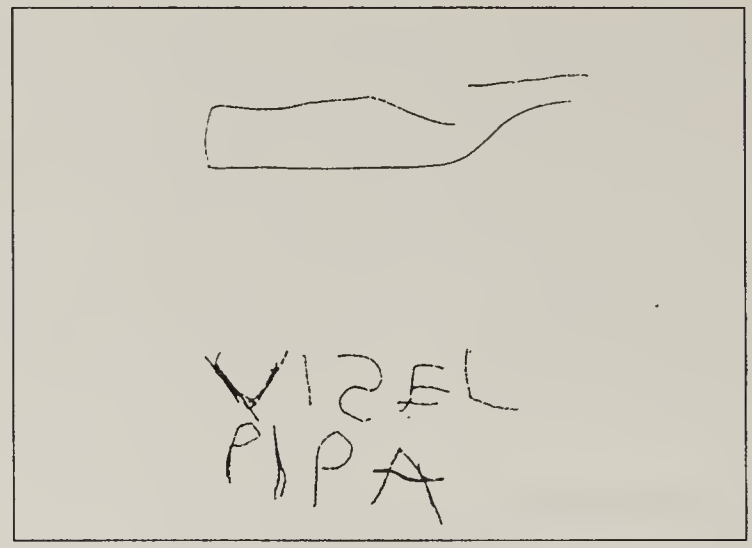
Series of drawings showing the sun.

A.

B.



C.

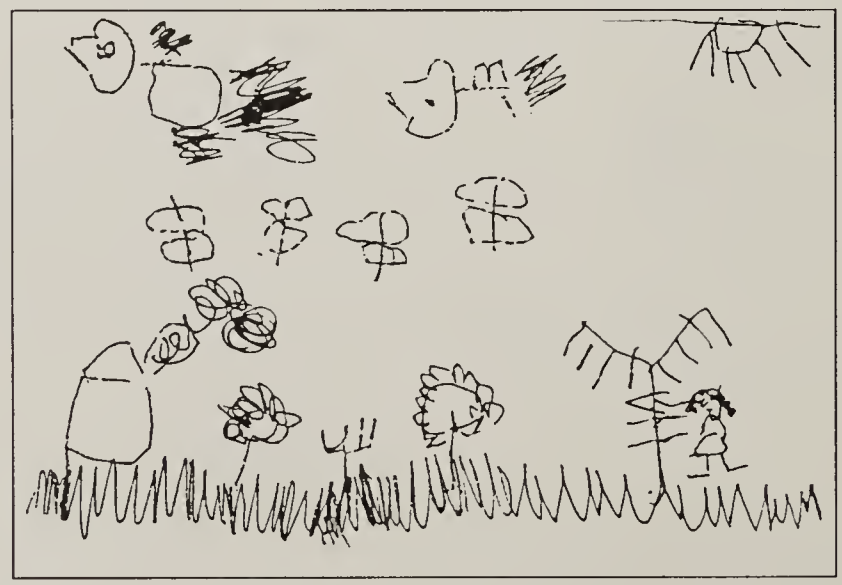


A whistle shown as an open form.

The same is true in the picture of a whistle shown here.

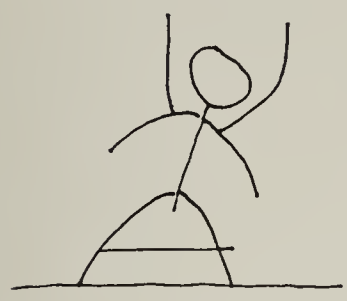
Pictures of drinking glasses are often drawn in the same manner. This open technique, used by most of the children I have known, has taught me to do the same in relief material of the one-elevation type—embossed displays or pictures produced on microcapsule paper. Test tubes, bottles, pipes, and illustrations for physics, chemistry, and engineering books are now open, unless closed by some obstacle. The children's drawings have been an invaluable source of information.

Just when I say that most children will draw in a certain way, an exception pops up. In a picture of a garden drawn by a 9-year-old blind girl and shown below, there is a house with smoke coming out of the chimney. If you look closely, you will see that the smoke is far down *in* the chimney before it comes out. You may also note that the chimney is closed. This picture has many similarities to those drawn by sighted children. The flowers are as large as the house. Above the garden are butterflies, above the butterflies are birds, and above everything is the sun.



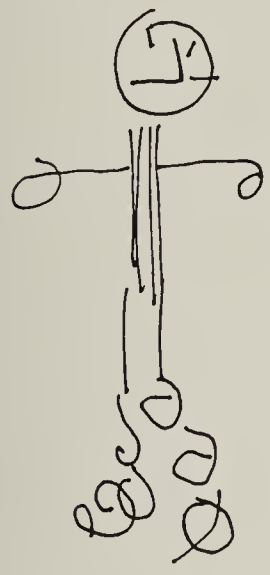
A garden drawn by a 9-year-old girl.

Blind children have their own way of illustrating action.



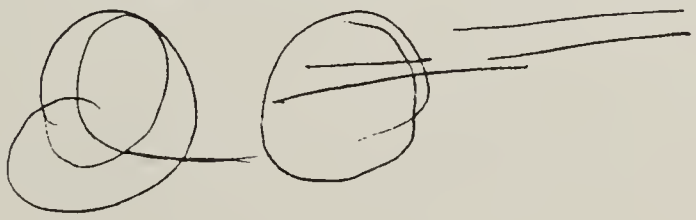
They draw people with more than two arms and two legs. Here for example, is a mother waving. She has four arms.

They repeat objects. Note this little girl with pigtails who is bouncing a ball.



Blind adults also have much to teach us. The raised-line drawing of a man walking that is included here uses the repetition of lines to show the steps that are being walked. The artist was a congenitally blind adult (Kennedy, 1982, p. 327).

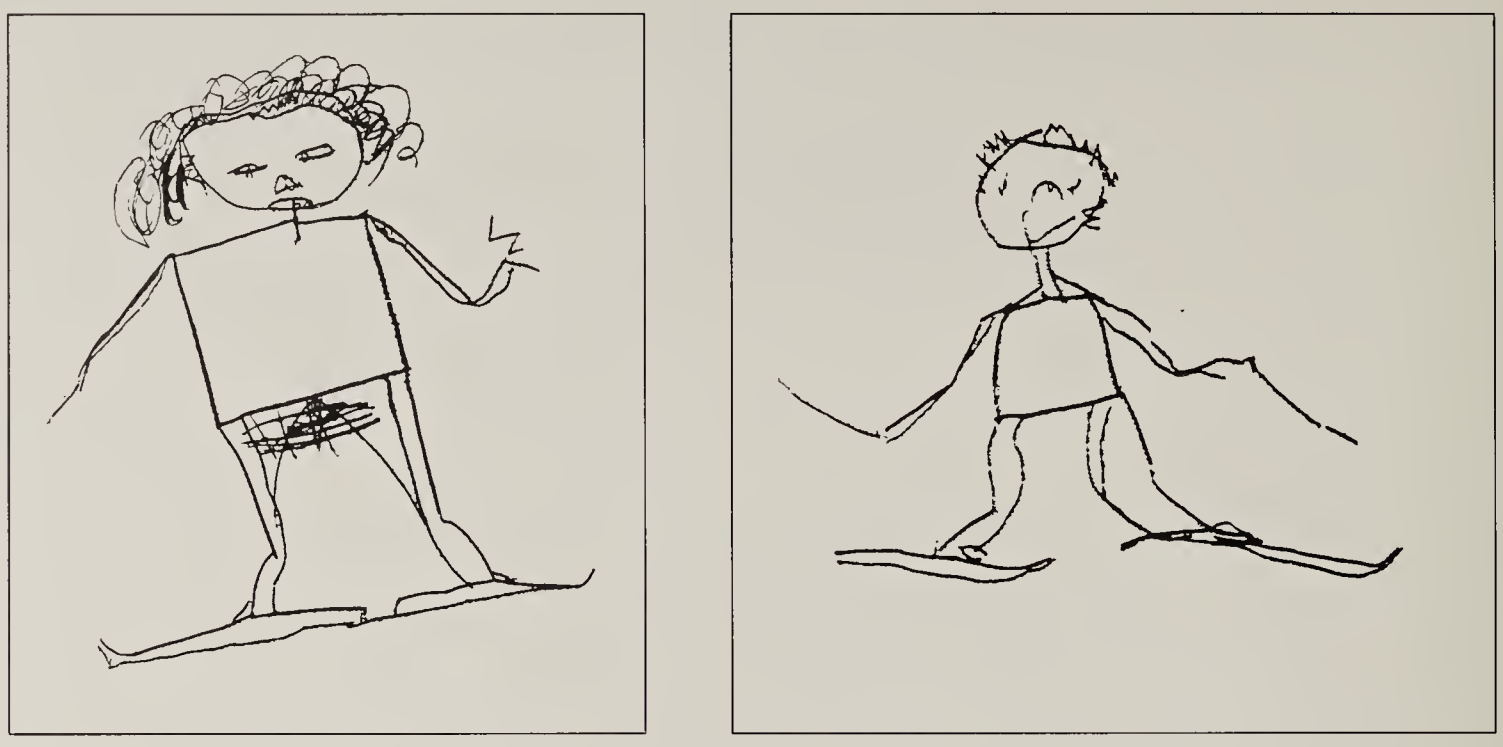
And here are fast-moving wheels.



Look again at the mother waving her arms—all four of them. This is action. A walking boar, drawn 50,000 years ago on the wall of a cave in Altamira, Spain (see ill. from Bradshaw, 1949), shows action in the same way. He has eight legs.

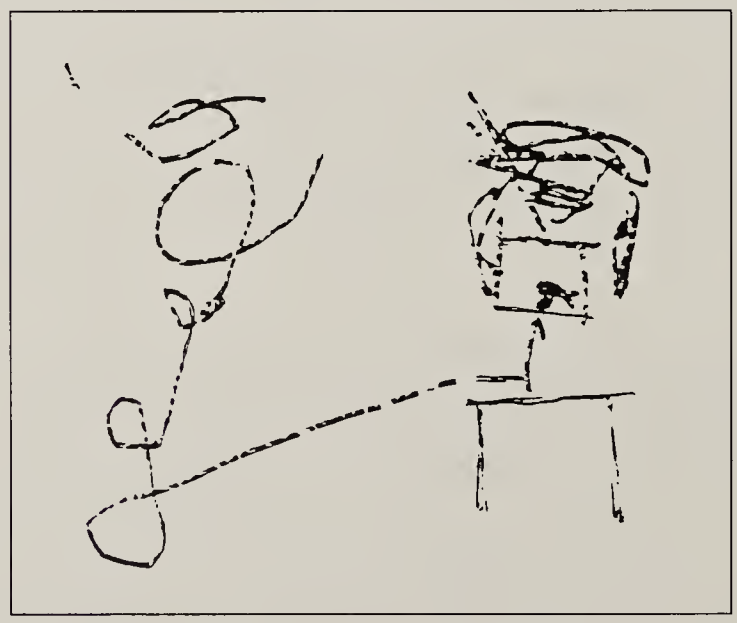
The two pictures of skiers shown on the following page (see A and B) also show action. Picture A was drawn first. When Fredrick showed it to the teacher, she said, "Do you really ski like that?" (The skis are pointed in opposite directions.) Fredrick thought for a minute, went through the motions of skiing, and then, without any outside comments or help, he drew the second picture.

In this cave drawing from *The Magic of Line* (Bradshaw, 1949), many legs are used to illustrate action.



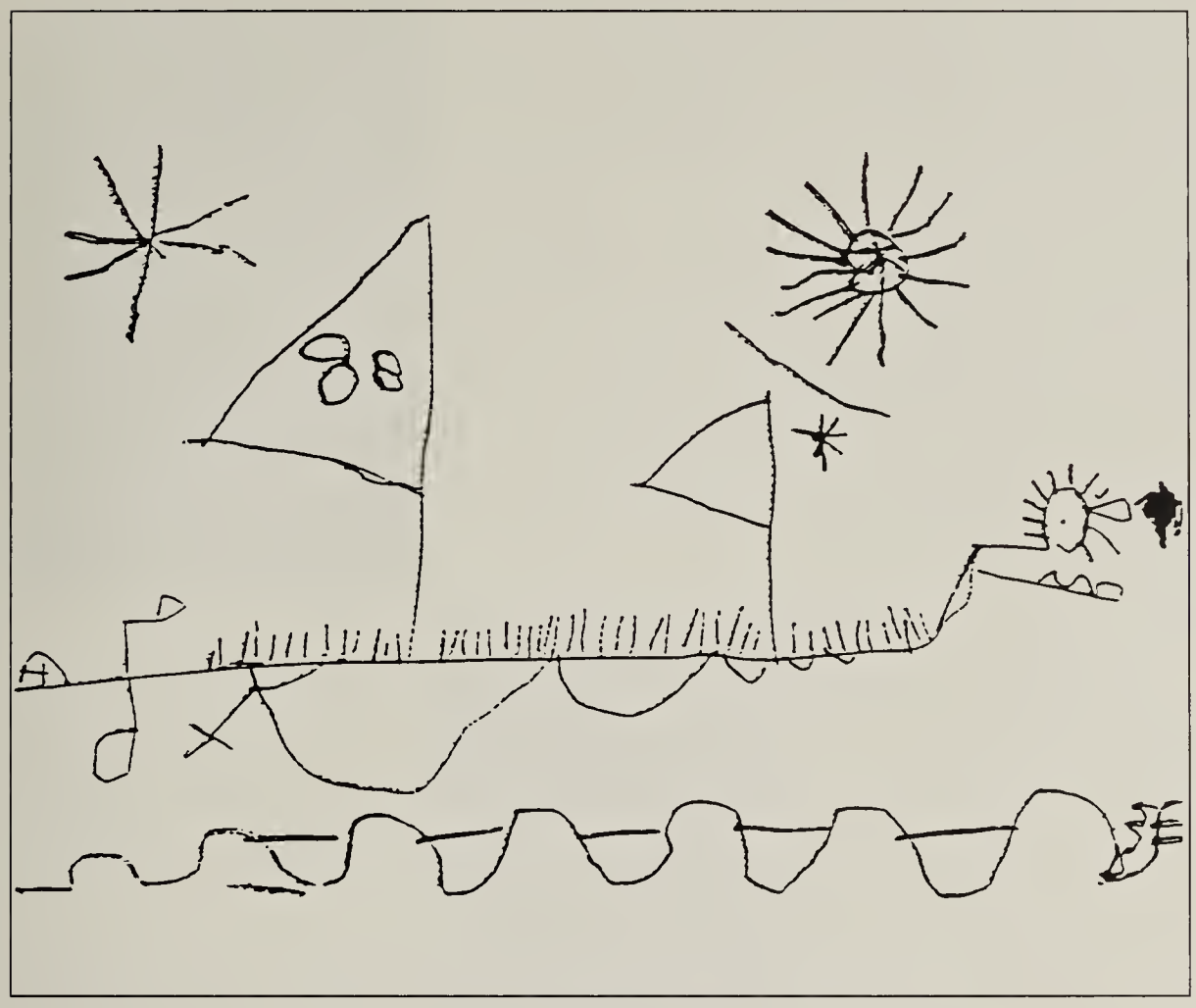
Two different drawings of skiers. A. B.

Heat and energy, although unseen, can be felt. The same 9-year-old boy who drew the three pictures of the sun shown earlier also drew the lamp on a table shown below. Around the lampshade are lines that indicate that the lamp is lit. The child felt the heat given off by the lamp. The wiggly line to the left of the lamp is the light cord, which he said was always getting tangled up. It sounded as though he had tripped on it more than once.



In this drawing, extra lines (*right*) convey the impression of heat and the extra-large size of the cord (*left*) conveys its noticeable presence for the child.

Some children have developed their own signs for particular situations. In the boat picture shown on the next page, the line under the sun indicates that the sun has gone behind a cloud; it is no longer there. To this young artist this means that it is time for the stars to come out; it is evening.

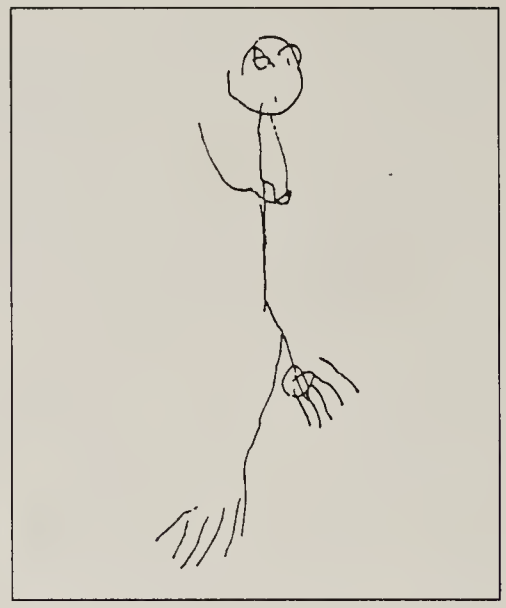


The line under the sun (*upper right*) in this drawing is used to show that the sun has gone behind a cloud.

Unknown to the 10-year-old boy who drew this picture, this line of thought is also reflected in an ancient Chinese ideogram. When the Chinese had an object that could be represented by a stylized picture, they made a picture symbol. But some things cannot be pictured, such as the word "not." To solve this problem, they drew three plants with a horizontal line above them. The line indicated that something had stopped the plants' growth. Consequently, the plants no longer existed, they were *not* there! It is strange how similar solutions appear to people who are groping for expression.

Other symbols in this drawing are the vertical lines along the deck. These lines represent people standing at the railing. The line across each wave is foam blowing off the waves. "It's a good day for sailing," the young artist said. The boat started out to be his father's sailboat and ended up as a Viking ship with a dragon head spouting fire. There was a great deal of conversation from this boy as his ship grew on the paper.

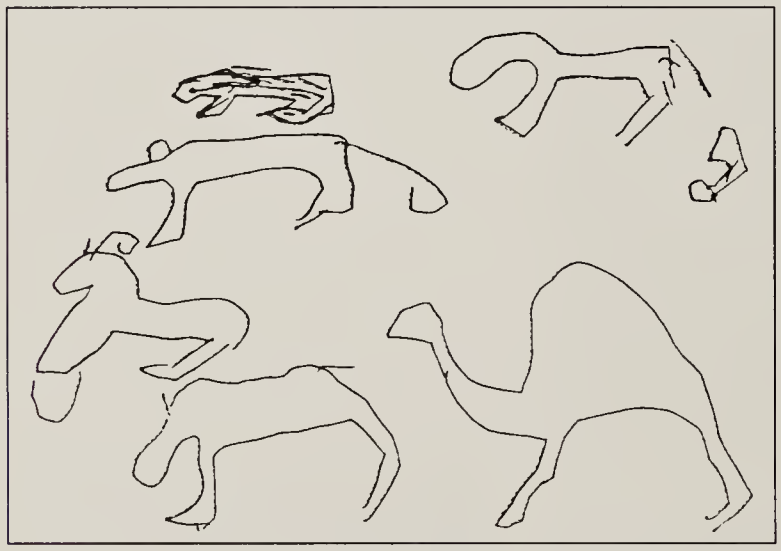
Blind children frequently draw people with very large feet or hands, as on the following page. Feet and hands are the blind person's primary points of contact with the ground, with objects. Consequently, they may be more important to a blind child than any other part of the body.



Enlarged feet (*left*) and oversized door elements (*right*) are prominent features of these drawings.

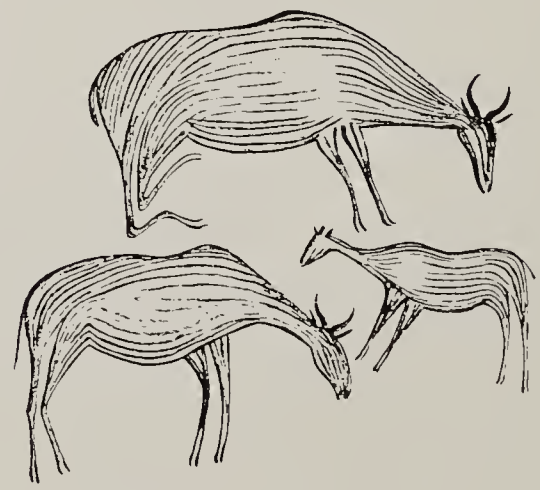
Enlarged elements on a house such as the one in the drawing above on the right also show the importance of contact. The door frame, bell, and handle are those objects the blind child comes into contact with in daily life. Therefore, they may be the largest in his or her mind.

Compare these drawings of animals by two 9-year-old blind boys (see A and B) with those done centuries ago by cave dwellers in Africa (see C). The two blind boys felt their animals



A. Porcupine (*upper left)* with quills; polar bear (*upper right*); leopard (*second row*); brown bear with hump on its back and dromedary (*bottom row*).

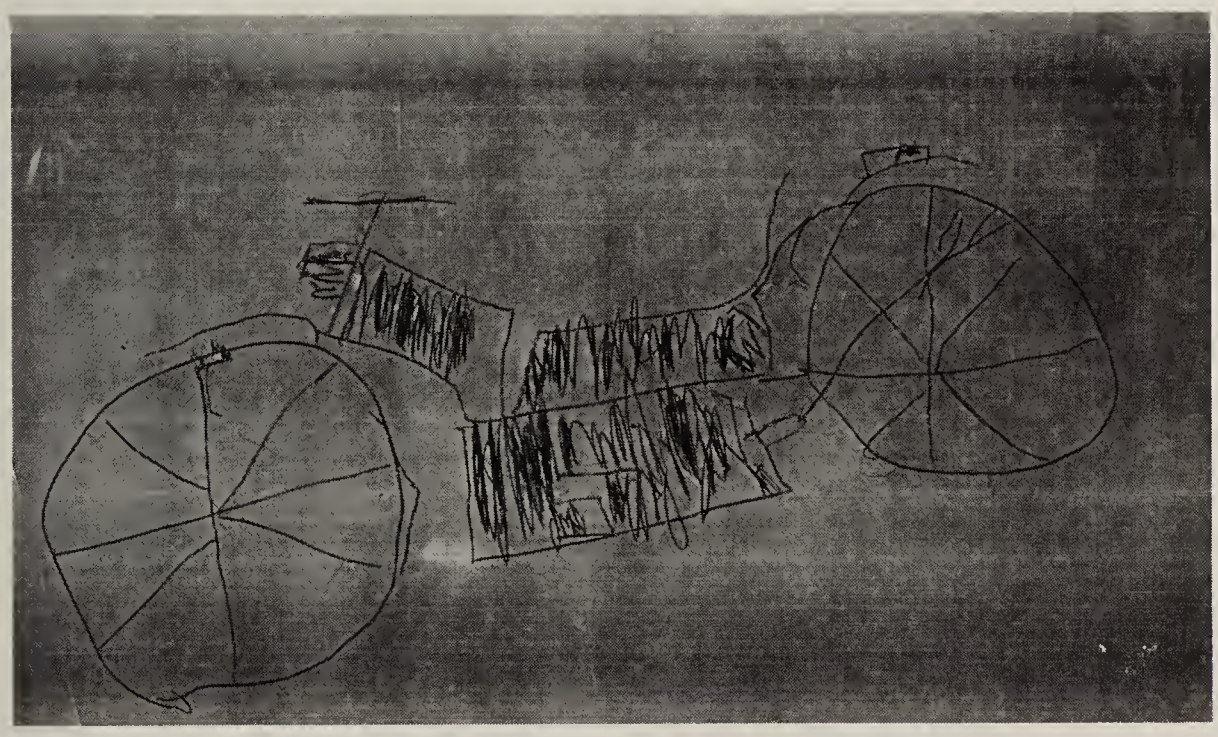
B. An elephant, a man, and decorative designs.



C. Cave drawing showing part of a herd of hartebeests, from *The Art of the Cave Dweller* (Brown, 1928).

in a museum. The cave dwellers saw the actual animals. All these artists drew without any preconceived idea of how the animals should look in a two-dimensional picture. Yet there is a definite relationship.

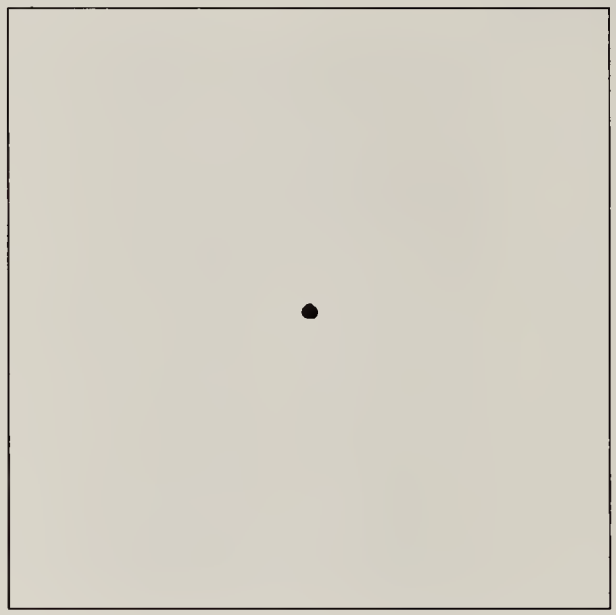
Blind children also use interior lines on their figures to give them a feeling of solidity, as one can see in the two pictures shown below. This technique was used on the man with the big feet, who is made up only of interior lines with no outline of the form at all, as well as on the solid form of the motorcycle also shown.



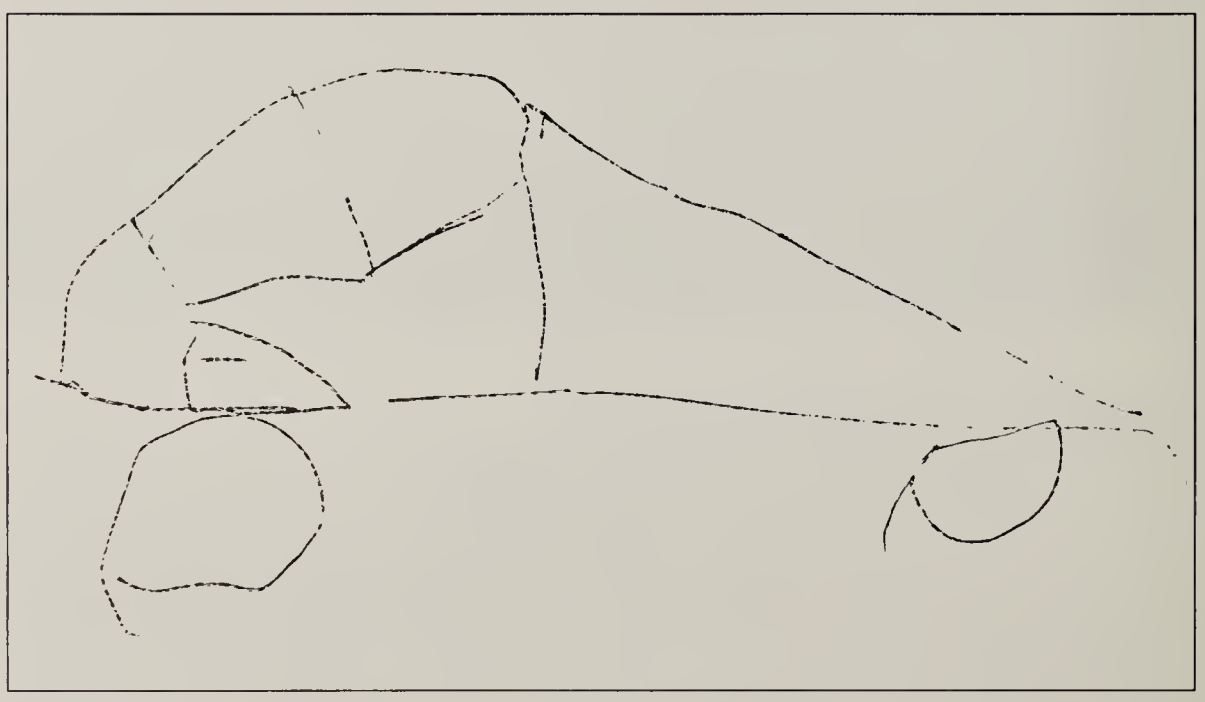
FINAL THOUGHTS

I have collected blind children's drawings for many years, and only one was nonfigurative. Perhaps the children have given me only those drawings that they thought I could understand. Who knows?

The nonfigurative picture had only a single dot in the middle of the page. "That," said the boy who drew it, "is a snowflake, which, by fate, was born on a hot day in July. It floated down to earth. Landed on a warm stone. Zzzzzz! It melted away and left only a tiny wet dot." You cannot portray emotion in pictures for visually impaired people, as can be done in books for sighted people, but this does not mean that the touch-reader cannot read his or her own fantasy into a picture.



There is a lot to learn from these children's drawings. And Anna's car shown here below is certainly more of a car as we know one than the car depicted by the Japanese teacher that is illustrated at the beginning of this chapter. When one realizes that the drawings shown in this chapter are the blind



Drawing of a car by Anna, age 7.

children's own interpretations of their surroundings, uninfluenced by the drawings of others or the visual appearance of things, then perhaps it could be said that these drawings are among the truest forms of art as personal expression.

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Brown, B. (1928). *The art of the cave dweller*. London, England: John Murray.

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CHAPTER 6
Maps

"Mobility may be defined as the power to move safely and easily from where you are to where you want to be . . . . Orientation is a clear understanding of where you have been, where you are, and where you are going."

—Richard Kinney,
Independent Living Without Sight and Hearing

A map reflects our surroundings, immediate and foreign. It is a two-dimensional display of spatial information. Relief maps in some form have been used for hundreds of years. Perhaps the simplest one was a map scratched into the ground with a stick—a finger tracing the grooves in the earth may have given a Stone Age person a better idea of his or her surroundings.

The same desire to know what is beyond one's fingertips is as vital today as it was yesterday. Blind and visually impaired people need to know more about their immediate surroundings to be able to orient themselves in a room, a building, a city, or a country—to be able to make their way independently.

OPPOSITE PAGE: Maps—the doorway to dreams and independent travel.

The lack of relief maps in many countries may be attributable to the time and cost involved in making a model, scarcity of information or ideas on how to make a map or a master for mass-producing maps, or absence of machines and materials to produce these maps. It is my hope that this handbook will be of some help in these areas.

However, the lack of relief maps could also be due to a shortage of information about maps that are already made in one part of a country but are unknown in another part of that country. Cooperation among producers will cut the cost of production and increase the availability of maps to a greater public. A map must be known to be used.

It is taken for granted that all who see can read a map. Yet this is not true. The interpretation of maps and pictures is a

personal, learned experience. How then is it possible for the visually impaired person to understand relief maps? It is up to us, the producers of relief maps and pictures in different parts of the world, to give visually impaired people all possible material that can be of help to them. We must take into consideration the particular needs of an individual and his or her background experiences, knowledge, and ability to interpret relief material. We must take advantage of the vast amount of research that is being done in this field and exchange ideas, materials, and production methods among countries to create better and more useful products.

Before making a relief map, clench your fist over a printed map. Open your fist just enough to peep through the hole made by the circle of your fingers. Move your hand well above the surface of the map, looking down through the tunnel of your hand. Try to piece the bits of information together as you scan the map. This exercise will give you some idea of what readers go through when they work with tangible graphic displays. It will also give you insight into the need for simplicity, clearness, and proper scale in your work.

A great deal of the information in this chapter is based on the research of Nancy Amick, John Armstrong, John Barth, Billie Bentzen, Edward Berlá, J.M. Gill, Grahame James, Gunnar Jansson, June Morris, Carson Nolan, and William Schiff, to whom we producers are extremely grateful (for recommended reading, see also James and Armstrong, 1976; Welsh and Blasch, 1980). The information in this chapter is applicable also, in some form, to all other phases of tactile displays mentioned in this handbook, and the information in other chapters is also important and useful in map making.

I will not go into the educational methods for teaching visually impaired students how to read and understand relief maps. The purpose of this book is production, not instruction in the principles and methods of teaching.

TYPES OF MAPS

There are several types of maps—those for instruction in geography, those for orientation, and those for mobility. Mobility maps seem to dominate this group in quantity and usefulness, no doubt because of blind and visually impaired people's

intense desire to know their surroundings and to be able to get around by themselves.

Mobility maps contain the location of local information and show the relationship of the various elements to each other. They are often referred to as safe-walking maps, because they give sufficient information for independent travel by a visually impaired person. Outdoor maps include information on buildings, streets, hazards, obstacles, and landmarks; indoor maps include information on building entrances, stairs, elevators, room layouts and numbers, corridors, toilets, and telephones. The scale of these maps is usually large.

Topological maps show the route of the blind traveler, with all the extraneous details excluded. The information shown is only for a visually impaired person. The scale and distances may vary from actual fact for the sake of simplification and readability.

Orientation maps offer a general survey of an area. They contain less detailed information than a mobility map and cover a much larger area. Their purpose is the same as that of the mobility map—to supply information for independent travel and about the relationship of the different areas and elements to each other. An orientation map may contain transportation networks, street layouts, shopping centers, recreational areas, and so on. A variety of environments, such as woods, parks, and cities, may be included.

General reference maps include the bulk of geographical maps, from small maps of one county to large maps of the world. These maps are often of two types: political and physical. Political maps contain cities, towns, roads, railways, airfields, and the like. Physical maps describe the physical characteristics of a country or area—its rivers, lakes, canals, mountains, volcanoes, land elevations, and so on. The size and scale of a political and a physical map of a single country or area should be made the same. The general scale is often small, since the area portrayed is so large.

Thematic maps or theme maps present qualitative or quantitative topical information on such things as population, industrial potential, climate, and so on. This type of map is used to display the occurrence, quantity, pattern, and structure of data and their geographic location. It is usually a small-scale map, because of the scope of the information displayed.

A map can be presented in many different ways, depending on the different types of visual impairment of the readers. People who are congenitally blind, have impaired sight, have diabetes and consequent diminished finger sensitivity, or do not read braille all have different map-reading requirements. The presentation also depends on the user's intellectual capacity and familiarity with relief maps and on the media in which maps are produced. Each person has a different need.

Before making a map, consider the following comments by a visually impaired map reader:

> The symbols on a map can appear in a staggering variety of sequences, depending upon the order in which they are touched by the hand. The tactile map reader may interpret the map differently each time it is encountered simply because the figures on the map are touched in a different order.
>
> The first step in efficient tactile map reading is proper orientation of the map. Start by searching for orientation clues. A title or legend, scale of miles, or even the direction of the tactile letters or numbers can all provide usable clues to the proper orientation of the map.
>
> Next, give the entire map a preliminary scan. A preliminary scan has been shown to significantly improve understanding of the specific map features. Scan in a systematic manner, being sure to cover all parts of the map. The preliminary scan will provide you with information about the size of the map, the kind, number, and location of symbols and the shape of bounded areas (Dixon, 1984, p.33).

With these reactions and tips in mind, try to lead your reader through your map, keeping it uncongested, the symbols easily differentiated, and the brailled information clearly defined and consistently placed in the same area on each map. You should also note that it may be necessary to obtain official approval of your national or local map before it can be used. Be sure to check with your national cartographic organization or department of land survey. Quite a few European countries have laws concerning the production of general and orientation maps of their country. This law is often designated as relating to "approval of distribution."

GENERAL GUIDELINES FOR MAPS

Simplicity

Keep the map simple. Each point, line, or texture must give vital information. Be restrictive. Ask yourself, "Is this information necessary?"

All information cannot be included on a relief map. The choice of detail depends on the mental capacity of the readers, their ability to read maps and to read braille, their background knowledge, and their ability to travel independently. Will they study the map without the help of a sighted person? Do not present more information on a map than is needed for the readers to carry out their task. A great deal of information leads to confusion and makes it difficult for readers to get an overall concept of the map. Vital information and the relationship of objects to each other may be lost in a clutter of details.

Excessively detailed displays tend to discourage elderly blind readers as well as beginning readers. The amount of information provided and the scale of the map are decisive factors in comprehension. Information can be divided into a step-by-step series of maps for easier reading and better understanding. Yet, spreading information over several maps may not be problem free.

Step-by-Step Techniques

It is often helpful to divide the information into two maps, one physical and one political (see A and B, next page). Keep both maps the same size and scale, and build them up on the same basic shape of continent, country, or area. The political map shows the location and name of cities, towns, roads, and national boundaries (A in this case also shows rivers). The physical map shows land elevations, locations, and names of mountains, rivers, and lakes. Cities are not included, and national boundaries are often excluded. Both of the maps of South America shown on the next page are made of cardboard, linen, and sandpaper, mounted on embroidery canvas. The dark labels are metal foil (to ensure long-lasting braille characters).

Note that when making a series of maps in the step-by-step

A. Political map of South America.

B. Physical map of South America.

technique, for one-of-a-kind or mass production, you should be sure to make patterns that can be used several times. File these patterns carefully. They are valuable to you when adding to that particular map series or when repairs and replacements are necessary on these maps.

For beginning readers, spread the information over a series of maps. For example, the purpose of the three maps shown on the next page is to present the country Brazil in a step-by-step process. The maps are made on microcapsule paper. The black lines and areas are raised, through heat, to a single elevation above the surface of the background. (Of course, these maps could also have been made in the buildup technique.)

1. Begin with the outline of the continent or area in which the particular country is located, in this case South America. Do not give details. Use texture to separate the land from the water.
2. Add national boundaries to the continent but no names or details. This allows the reader to feel the different countries without the distraction of braille letters or numbers. Tape labels can be added to the map later, if desired.

1. Basic outline without details.

2. Basic outline with national boundaries added.

3. Map with texture added.

3. Add texture to the particular country to show the relationship of the country to the continent. You can also use this technique to show a particular area within a country. Two maps can be produced from the master for step 2. One map can be used as a background, and the other map can be mounted on thin cardboard. The desired country or countries can be cut from the cardboard-backed map and used on the background map as puzzle pieces or to increase emphasis of a particular area. The country to be studied can be cut out and mounted over the same country on the background map. This technique is explained under "Special Emphases" in Chapter 2 by using the example of a turtle and its shell. This same technique is also applicable to maps 4 and 5 shown on the next page.
4. You can also show the particular country, in this case Brazil, by itself, separated from the continent. You can add rivers, lakes, mountains, and cities on one or several maps. If the scale of these maps is enlarged, the reader must be informed. Otherwise, he or she may wonder if Brazil and South America are the same size. For the beginning reader, the scale could be explained as being two, three, or four times as large as the country shown on the continent. Scale is important and should appear numerically on all maps. The earlier a reader learns the meaning of the scale of a map, the easier it will be for him or her to understand the information presented.

Keep these maps very simple. The reader must learn to read the map, to assimilate the components and put them together in his or her memory bank. This is not an easy task!

When making a series of microcapsule maps (see also "Microcapsule Paper," Chapter 2), do the following:

4. Microcapsule map with braille text for each country.

- Use the original or basic map (see map 1, page 199). Before adding braille text or water texture to the outline map, make two copies in a copying machine.
- Put one copy aside for later use. Add water texture to the other copy and make two copies of this copy. Add braille text to one of the copies (see map 1). Add national boundaries to the other (see map 2, page 199).
- Make several copies with national boundaries. Add a texture to the particular country (see map 3, page 199). Another copy may be used to add braille labels to the countries on the continent (see map 4) or for future use when making maps of other countries on the continent for these same readers.

5. Microcapsule map for low vision readers.

Remember, it is easy to make copies along the way while working on a series of maps. Save yourself the trouble of redrawing maps or painting out details that cannot be used on the next map. Think ahead. What will you need?

The maps shown here (4 and 5) are based on two of these copies. Map 5 is made for readers with reduced sight, including those who cannot read braille. The simplicity and sharp, black relief lines make these maps especially useful to this group (see also Chapter 9).

Inkprint book page showing the cities, rivers, and mountains of Brazil, from *Nya Gena 3 Studiebok B* (Rystedt, Andersson, Bladh, Kohler, and Thorén, 1982). Numbers on the map correspond to questions asked in the textbook.

A Textbook Problem

Following is another series of microcapsule paper maps illustrating a step-by-step presentation of Brazil. The series was created to solve

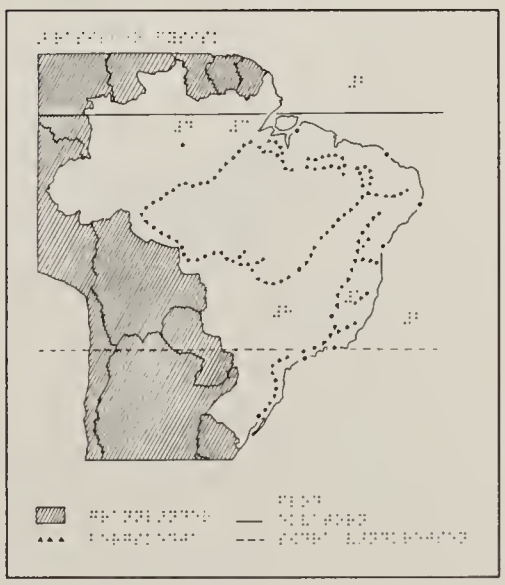
the requirements of a map in a textbook for sighted students that is shown at the bottom of page 200.

1. The first map shows Brazil's position on the continent of South America. No names or numbers interfere with the reader's opportunity to obtain an overall feeling of the country and its system of rivers.
2. The second map shows Brazil's mountains added to the river pattern. Both the mountains and the rivers will be named on a larger map of Brazil that shows the country by itself. The reader now knows that the country is quite mountainous. The names are immaterial at this point.
3. In the third map, unnecessary information has not been included. This map takes in only those places that are numbered on the original textbook map. This system seems to work well with younger readers. However, it is difficult to combine information so that the reader will know which city lies beside which river.
4. Therefore, a fourth map, containing the most important items of information from all three maps, is a valuable addition to this series.

3.

2.

1.

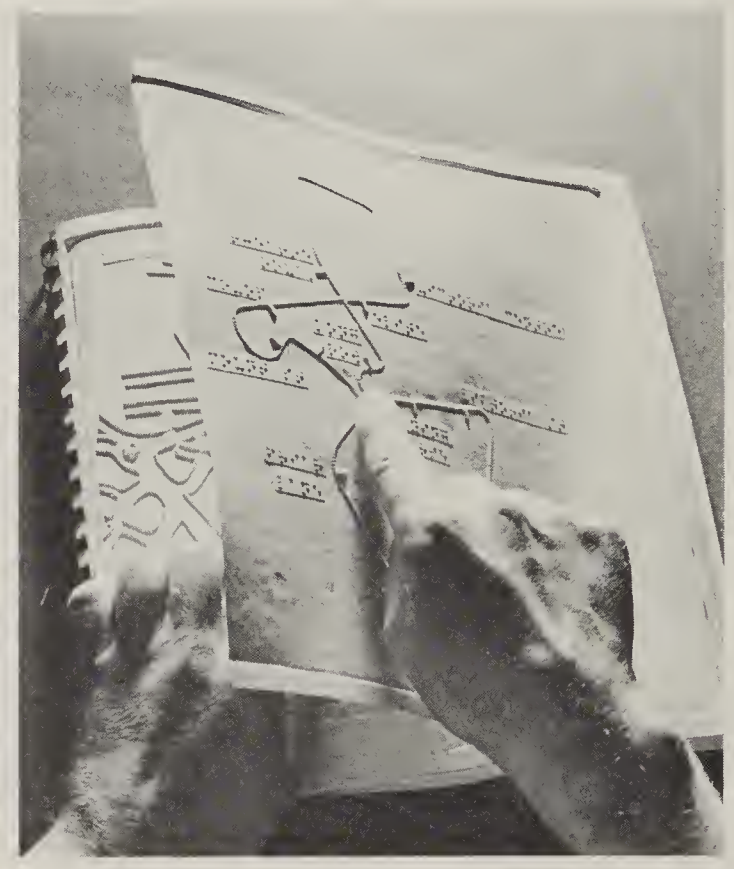


4.

Suggestions for Making Mobility Maps

Mobility maps are discussed in detail later in this chapter. In regard to the present topic of dividing up information for the reader, however, the following principles apply for these maps:

- Make two maps in different scales, one to give a general impression of the area and the other, on a larger scale, to contain enough detailed information to allow the reader to move independently within the area.
- Make two or three individual maps of the same area, containing different information. These maps could be fastened together so that the reader could fold one sheet over the other, as shown below. In this way, a bus line or a special route to a particular place could be placed over a map of the city showing the location of particular buildings (see "Overlays and Underlays," this chapter).



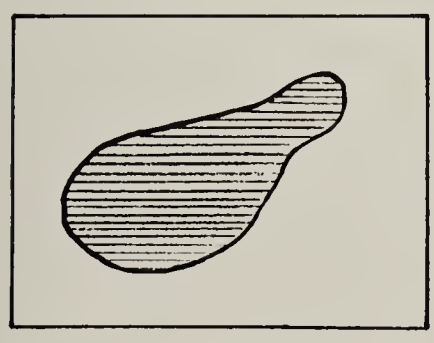
These maps are fastened together in such a way that they can be folded over by the reader.

- For more suggestions for simple mobility maps, see the discussions about displays with movable parts, flannel-board diagrams, magnetic-board diagrams, self-adhesive instant display systems, and cork maps and graphs in Chapter 2.
- A well-organized key for each map will simplify the map and dispense with unnecessary words and arrows within the display (see "Key or Legend," Chapter 4 and this chapter).

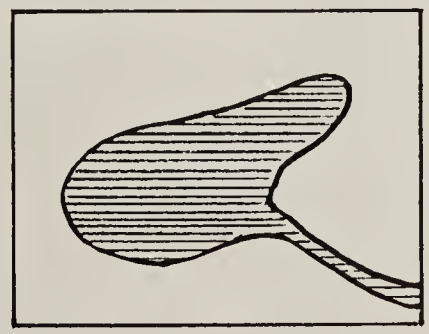
EARLY MAP TRAINING

The ability to read and understand a relief map is not an automatic skill for visually impaired people. The map reader must be trained to recognize and understand the relief material, the point and line symbols, the use of areal texture, and the use of the key that unlocks the information on a particular map. Various techniques can help train readers to use relief maps.

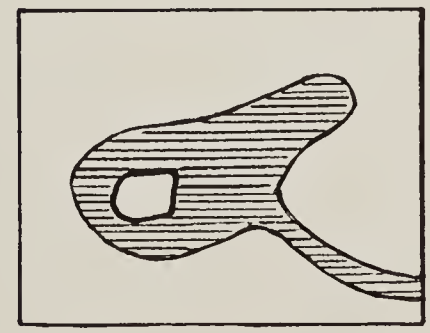
- Make large sheets of solid texture, a different pattern on each sheet. The size should be smaller than a sheet of typewriter paper, or about 6 in. by 8.5 in. (15.2 cm by 21.6 cm). (For patterns, see "Areal Symbols," this chapter.) Make sets of small cards of the same textures. Have children find the matching textures.
- Make two sets of small cards (the size of playing cards) with allover textures. Glue one complete set to a background material. Have children match the second set of texture cards with those on the background material.
- Many of the basic geographic concepts that are common to sighted children are virtually unknown to their visually impaired classmates. Therefore, it could be advantageous to make a series of fantasy maps—a step-by-step process of adding new information to each map—that will build up children's vocabulary and recognition of geographic elements (see A, B, and C). The maps should be of a size that is easy for the young reader to scan and handle, approximately 6 in. by 8.5 in. (15.2 cm by 21.6 cm). There should be no braille or printed text on these maps.



A. Fantasy map with land and water.



B. Map with land, water, and river.

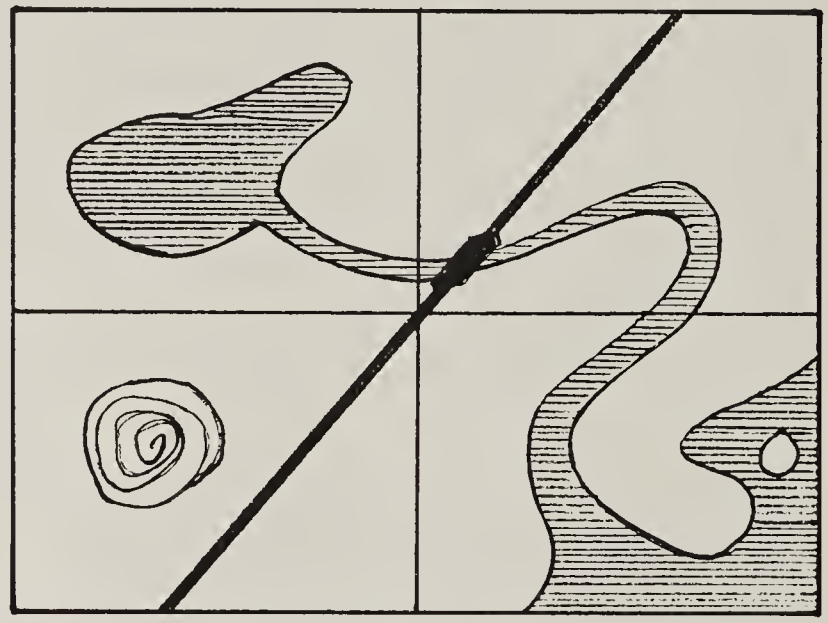


C. Map with land, water, river, island, and so on.

An accompanying sheet or card could contain the same symbols and their braille names. This sheet would prepare the child to read a map key. The series of maps and key

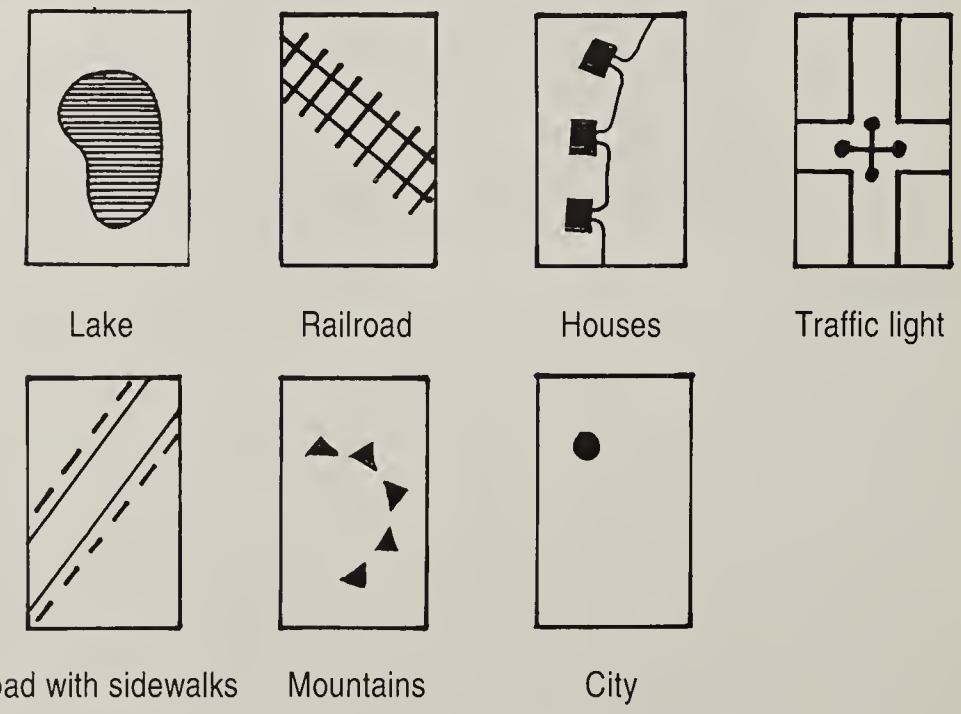
cards could be made up into a standard set that could be used by several classes or schools. Color could be added to the maps for readers with low vision.

The maps can also be made so that one set can be used with another set. The result would then be a four- or six-section map (see below). Children could make up their own large map, since the smaller maps could be interchangeable. The maps could be taped to a tabletop or fitted inside a shallow frame made out of a cut-down box.

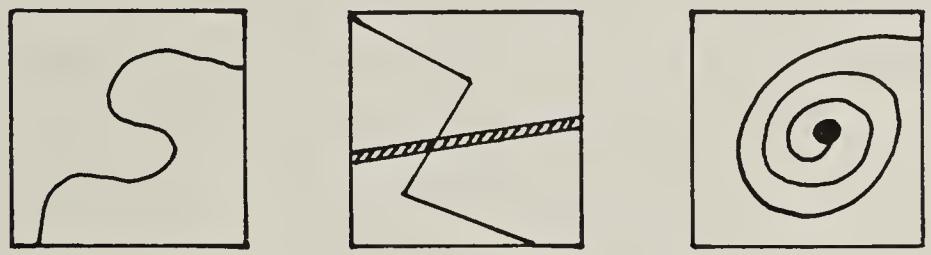


Recognition Cards

- Make two sets of recognition cards like those shown here, one symbol on each card in the one set, and one symbol name on each card in the second set. With these cards, a child can increase his or her ability to recognize symbols. Two children can use the cards to play matching games.



- Mount one or more shapes on a firm background. Cut out the same shapes in cardboard and have children find the corresponding shape on the board. This project can be made into a puzzle if the shapes on the background are reproduced in a vacuum-forming machine. Reverse the plastic copy and have children fit the corresponding forms into the indented areas (see "The Puzzle Technique," Chapter 2).
- Make sheets of lines, one or more to a sheet, to train children in tracking a line.



- Gradually give children a combination of symbols.

- Make simple models and maps of an area familiar to children (their classroom or room at home, for example). It is easier for a child to relate an abstraction (the map) to a known area than to an unknown area. Different textures or shapes could represent furniture or objects in the room. Do not include too many items.

  The complexity of the maps can be increased gradually by the addition of symbols to represent other features when the reader understands the relationship between the room or area and the map.
- Ask blind children to draw their own maps on their raised-line drawing boards. Their drawings will indicate to you how well they understand the principle of a map and may give you valuable information on how they see things and their way of interpreting their surroundings.

The Use of Labyrinths

A labyrinth is a maze of pathways separated by connecting walls, some of which may end in a cul-de-sac. When a labyrinth is made into tactile form, following its path increases

the ability of the visually impaired reader to trace a line or a corridor and affords an enjoyable, stimulating activity. The use of labyrinths therefore provides excellent map training.

A series of relief labyrinths, most easily produced on microcapsule paper, could include a range of figures from the simplest to the most complicated. This type of book would appeal to readers of all ages. The Danish School for the Sight Handicapped has produced two such relief books, *Taktile Labyrinter*, by Edith Saltbaek and Astrid Skov. The text is in Danish, but this does not affect the use of the large, excellent illustrations. The books contain 14 and 15 labyrinths, respectively, and are made in the school's own braille shop. They offer hours of interesting and challenging entertainment for both blind and visually impaired readers. For additional information, contact Refsnaesskolen, Institut for Blinde og Svagsynede, Kystvejen, DK-4400 Kalundborg, Denmark.

SYMBOLS: GENERAL INFORMATION

The word "symbol," used in association with relief maps, often refers to point, line, and areal symbols as a group.

Point symbols designate specific locations of objects. They are symbolic and do not indicate the shape or size of the object. A point symbol on a general reference map can identify a major city; on a mobility map, the same symbol might indicate a bus stop. A point symbol can also indicate the source point of sounds and smells.

Line symbols indicate both location and direction and are made up of lines of various sizes and designs. They are symbolic and do not represent the actual height or width of the objects portrayed, which could be a national boundary, a road or street, a subway system, a river, and so on.

Areal symbols represent definite areas on the map as seen from overhead. They are textured areas that indicate the shape, size, and location of countries, oceans, land elevations, areas of vegetation, buildings, parks, lakes, and the like.

The standardization of symbols for relief maps has been discussed in many countries for many years. There are as many opinions as there are map producers, and standardization is often difficult even within a single country. The use of various production processes also complicates standardization. It is

difficult, if not impossible, to use the same symbols in raised-line drawings, plastic copies from the vacuum-forming process, microcapsule paper displays, and computer diagrams.

However, there has been some progress in this field. The Nottingham Map Making Kit (see "Paper Buildup Displays Using Additional Materials," Chapter 2) was a step in this direction. The kit was a collection of material to be used in making a map master for the vacuum-forming process. The prefabricated point symbols, soft solder strips for line symbols, and textures for areal symbols have become a basis for symbol systems in many countries. Constant research on the acceptability of different symbols is being carried out. There are no set rules about their use. However, the following suggestions concerning all three types of symbols—point, line, and areal—are well proven and can be followed with reasonable success, depending on their application:

- Number of symbols:

  The difficulty in identifying individual symbols in a display increases as the number of symbols used in the display is increased. (This is also true if there are too many symbols within a particular area of a display.) Added information on a map, or on any other type of display, may not always mean added information to the reader. Consider spreading information over several maps or using overlays and underlays, discussed later in this chapter.
- Distance between symbols:

  Spacing between symbols and patterns must be greater for tactile perception than for visual perception. Relief symbols take up a much larger area on a tactile map than inkprint symbols do on a printed map. It is therefore important to be restrictive in the choice of information that is to be included on the map.

  Symbols that are tactilely different one from another can be confused with each other if placed too close together. It has been mentioned previously that, for good discernibility, the distance between symbols should *not* be less than 1/8 in. (3 mm), the approximate distance between two braille cells. A greater distance is required as the symbols decrease in size. It may be necessary to enlarge the scale of the display to gain sufficient distance between symbols.

- Elevation of symbols:

  Maps with point, line, and areal symbols of various heights from the background material are more easily understood than are maps in which the three types of symbols are relatively similar in height. Tactile perception is highly sensitive to differences in elevation. It is recommended that in tangible diagrams, the areal patterns should be lowest in elevation, the line symbols should be a bit higher, and the point symbols should be the highest.

  Clutter and confusion can be partially eliminated by the use of different elevations for different symbols, according to selected standards: braille, .02 in. (.5 mm); areal symbols, .02 in.-.04 in. (.5 mm-1 mm); line symbols, .04 in. (1 mm); and point symbols, .06 in. (1.5 mm) (see James, 1982).

  The following information on the four main, or standard, levels for town maps was presented at the European Symposium on Tactual Town Maps held in 1983:

  Level 1, the lowest level, is .08 in. (2 mm) above the background or base; it is used for streets.

  Level 2, .12 in. (3 mm) above the base level or .04 in. (1 mm) above level 1, is for pavements, bus stops, street names, and so on.

  Level 3, .14 in. (3.5 mm) above level 1, is for tall buildings. Bridges and constructions of similar character come between level 2 and level 3.

  Level 4 is for high-rise buildings, tower blocks, clock towers, and so forth and provides useful points of reference.

  There is little difference in elevation in embossed paper maps or in microcapsule paper maps. Therefore, when you use these production methods, it is especially important to choose a few symbols that can be easily differentiated in the same display.

  Remember that variations in the height of the different symbols, lines, textures, and shapes is essential because the reader gains the greatest amount of information from these differences in elevation. A well-defined contrast in the shape and texture of the elements of a tactile graphic display, a simple layout, and variations in height make for a high degree of reader comprehension. This combination of factors cannot be stressed too often. It is the essence of tactile graphics.

- Texture:

  Color marks the importance of certain areas in an inkprint diagram. Contrasting textures, from rough to smooth, and contrasting elevations are color substitutes for the visually impaired reader.
- File of symbols:

  Keep an active file of different point, line, and areal symbols with a description of the materials used and the methods of production. If possible, include samples of the symbols on a master, plastic copies, and microcapsule copies, noting the materials used, their availability and durability, and readers' acceptance of them. A file will help you with future productions by showing you what can and cannot be done. It will help you to choose symbols that work well together and may stimulate you to create new symbols, methods, and combinations.

POINT SYMBOLS

Symbolic figures that are used on relief maps to designate the specific locations of objects and source points of sounds and smells are called point symbols. Braille characters and certain uppercase letters can also be included in this group of symbols, as shown in the recommended symbols presented below. These figures do not indicate the shape and size of the object they represent (see Nolan & Morris, 1971).

Recommended point symbols (*actual size used in research tests*).

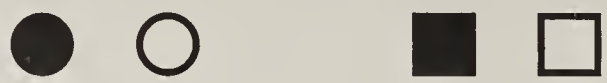
Suggestions

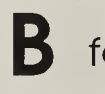
- It is often easier to discriminate a point symbol shown as an outline than a point symbol shown as a solid form when the symbols are of a good size. This is not true of minimum-size symbols.
- Point symbols should fit under the reader's fingertips but be large enough and of such an individual character that the reader can easily find and understand them. Variation in shape, size, outline, and elevation from the background material makes it possible for the reader to differentiate among symbols. If similar forms are used on the same map,

they should differ in regard to at least two of the factors just mentioned, as these circles do:

This circle is more easily distinguished from this circle if the solid circle is made with a rounded surface instead of a flat surface .

- Certain symbols can easily be confused when used together if the evenly embossed surfaces and embossed contours of the same-size forms are placed adjacent to one another.



- Variations of the basic geometric figures, such as , can be easily confused with when they are used together in the same display.
- Symbols should not be excessively figurative. A simple symbol is more easily understood than a complicated one. The most important thing is that the reader understands the purpose of a particular symbol. Symbols, including braille characters and printed letters, are more easily understood if they can be associated with the object they represent. For example, stands for a telephone booth (symbol from the Nottingham Map Making Kit; see "Symbols in Use Today," this chapter), for a church, and  for a biology room. You need a key to explain the use of the different symbols used on the map or diagram.
- Small shapes, such as a square and a triangle, are difficult to recognize if they measure less than .20 in. (5.1 mm) on one side.
- A sharp, clean-cut edge attracts more attention than a rounded edge . This is also the case with line symbols.
- The rougher or higher in elevation a point symbol is, the more it will be noticed. However, be restrictive when using this technique. Decide which point symbol is most important.
- Keep the 1/8 in. (3 mm) rule: a minimum of 1/8 in. between adjoining tactile symbols!

- A point symbol embedded in an areal pattern will be difficult to find. A blank area of 1/8 in (3 mm) around the point symbol, and preferably even more space than that, will make it easier for the reader to locate the symbol. This is an absolute necessity in displays having only one elevation raised from the background surface (see "Mountains," this chapter).
- Identical symbols should always appear in the same form and size in the same display or in a series of related displays.
- Braille characters may be confused with other symbols with a small surface area. To avoid confusion, make the braille characters a different height from other symbols of a similar character, according to the standards for the elevation of characters presented in the section "Symbols: General Information."
- The most usable uppercase letters in an embossed form are A, B, C, E, F, H, I, J, L, Q, P, R, S, T, U ,Y, and Z. These letters were recognized with a high degree of accuracy in a study by Schiff (1966). The letters in the test program were .56 in. (1.42 cm) in size.
- To make circles or dots, you can use a braillewriter or slate and stylus; a freehand drawing stylus (see "Embossed Paper Displays," Chapter 2); a metal paper fastener (see "Answer Cards and Pop Sheets," Chapter 2); small nails; a snap fastener used on people's clothing; small sequins or buttons; knots on the end of thread or string (see "Paper Buildup Displays Using Additional Materials," Chapter 2); contour paste (small drops made directly on the master and allowed to dry), dry-transfer dots of different sizes; inking pens and circle stencils; or felt-tipped pens.

  Hand-punched dots of various sizes can be made from paper, cardboard, sandpaper, plastic, metal foil, leather, cork, or cloth saturated with glue (see "Making Changes on a Paper Buildup Master," Chapter 7). If the display is to be mass-produced, test the materials you choose to make sure they can withstand heat before using them in a vacuum-forming machine.

Arrows

The arrow is a symbol that is halfway between a point symbol and a line symbol. The section "Arrows," Chapter 4, discusses

the symbol used in pictures. That section is also applicable to arrows used on maps.

Arrows can be used to indicate the physical properties of the ground or street, inclining or declining; to show the direction of stairs, up or down; and to point to the entrance or exit of a building or a room. These symbols and the information for which they stand should be noted in the map key. Certain maps I have seen of Boston, made in the United States, have rough surface arrows, on the lines representing streets, to indicate the direction of the traffic.

The placement of a north arrow (see "North," this chapter) or a reading-direction arrow (see "Arrows," Chapter 4) obviously indicates its function. However, make sure that other arrows used on the map do not become confused with these arrows.

Be restrictive in the use of arrows. They clutter a map and add to the reader's confusion if they are not essential. Arrows are supposed to make it easier for the reader to understand the display. Do your arrows do this? Consider whether a verbal or written description would be easier to understand than would an arrow.

LINE SYMBOLS

As a group, line symbols consist of lines of various sizes and designs. The lines indicate both location and direction but do not represent the actual width or height of the objects portrayed. The line symbols discussed here are raised lines. This type of line seems to be more easily recognized and traced than incised lines.

Types of Lines and Variations

There are many ways to vary a line. It can be solid, dotted, dashed, or a mixture of all three. It can be wide or narrow, thick or thin, smooth or rough; it can have a track or a furrow, appear in a pair or alone, or have straight or rounded edges. It can be loud in importance or a mere whisper of a fine, fine line. Without lines there would be no maps, pictures, or graphic displays.

Line symbols should be easily discernible from other symbols in the display and should be meaningful and informative. They

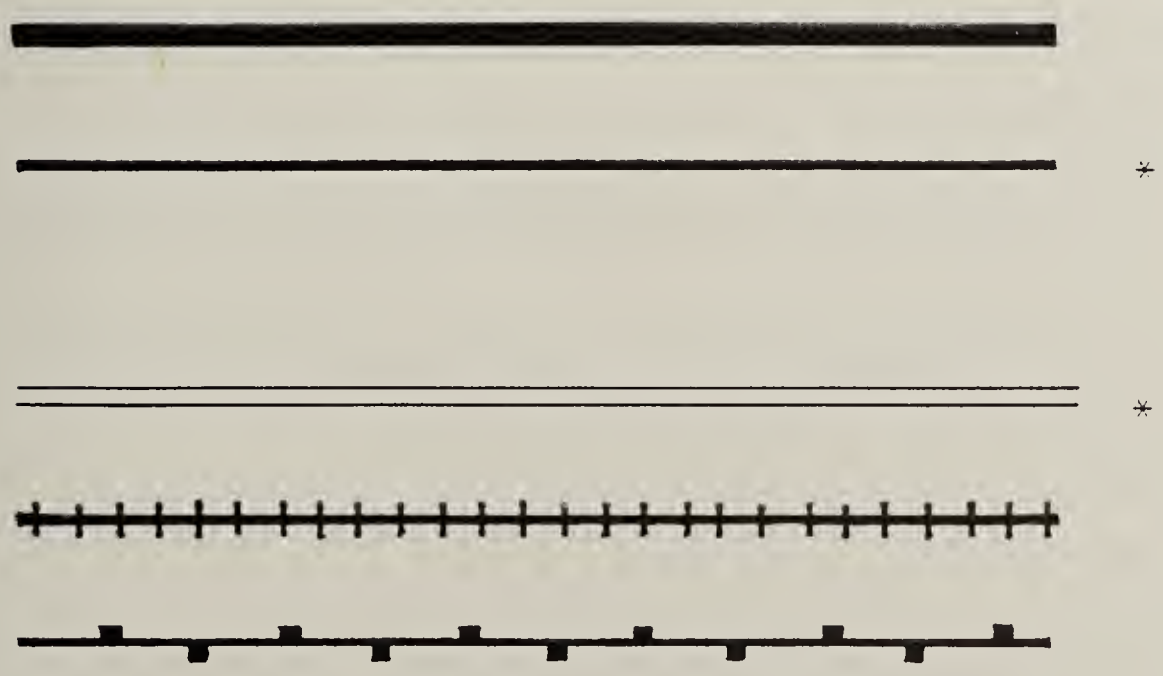
should also be easy to trace by the reader with reasonable speed and accuracy and without getting lost. Ease of tracing is determined through choice of size and texture. Proofread with your fingers because a design made by eye can be misleading.

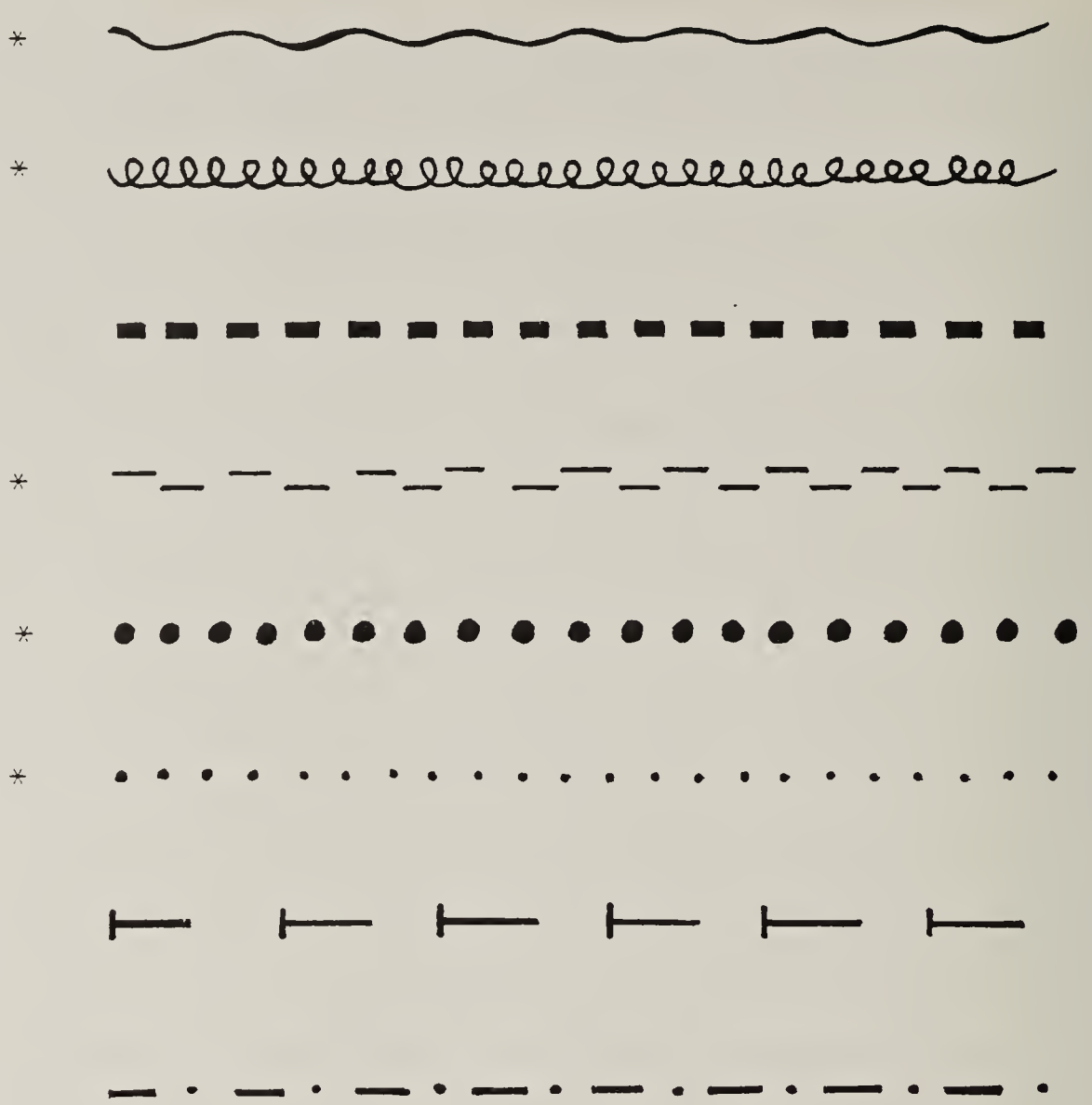
There should be a difference between lines in a display:

- Structural lines give the figure, object, or country its actual form or structure.
- Important lines emphasize certain areas through size, texture, and elevation and are meant to catch the reader's attention.
- Information lines, although not an integral part of the picture or map, are necessary to connect various parts of the display, to show distance between definite points, to indicate direction, and so on. A single dotted line connecting information with a particular point in the display is often used in the place of an arrow.

Before beginning work on a relief display, analyze the material that is to be transposed. Evaluate the different lines according to their purpose and importance. This is especially necessary in one-elevation reliefs, where all lines are of the same height.

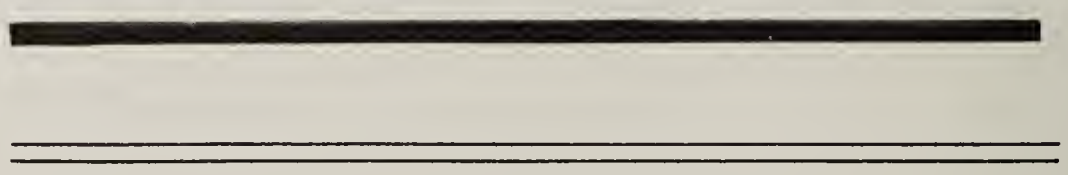
The following line symbols were tested by Nolan and Morris (1963) in the same size as they are presented here. Lines marked with an asterisk are recommended.



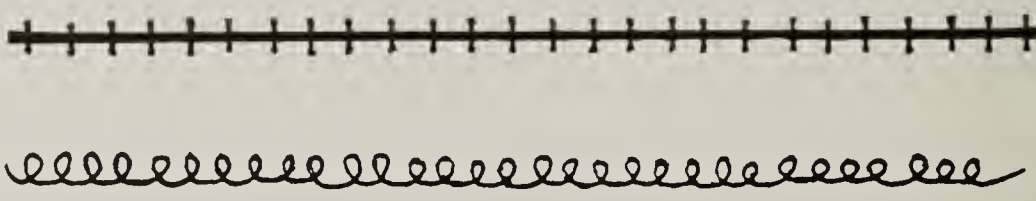


The following types of lines are often confused if used together on the same display:

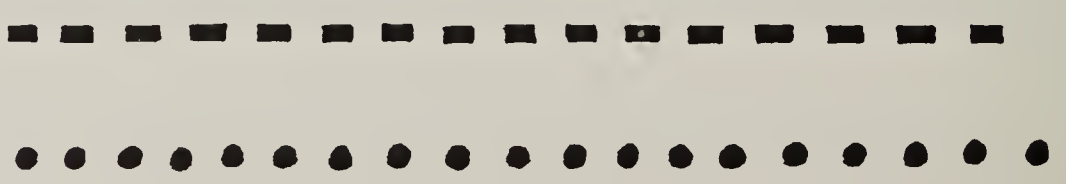
- a single straight line and a double line of the same width,



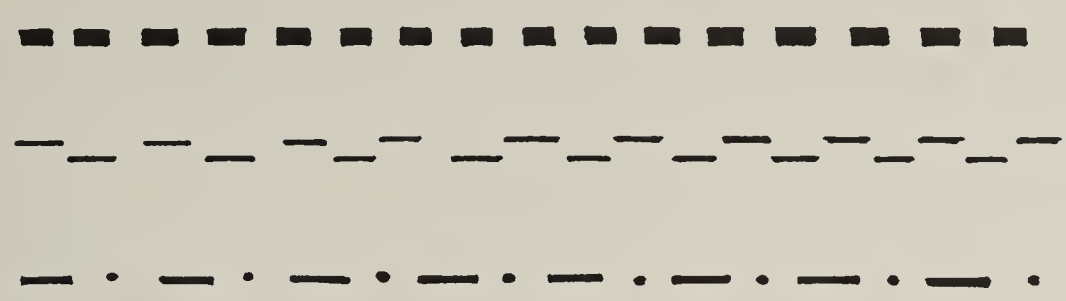
- a straight line with crossing short bars and a spiral line,



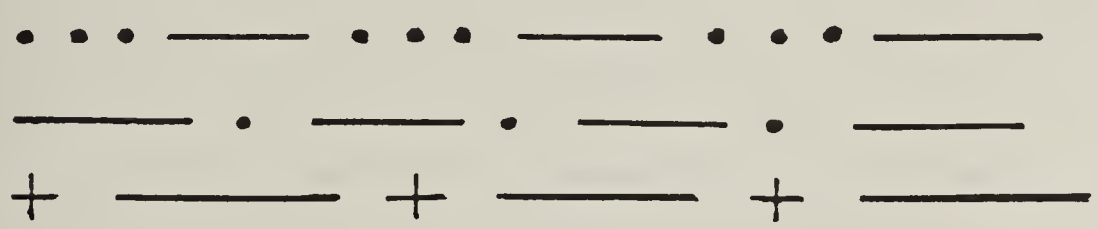
- different types of broken lines together



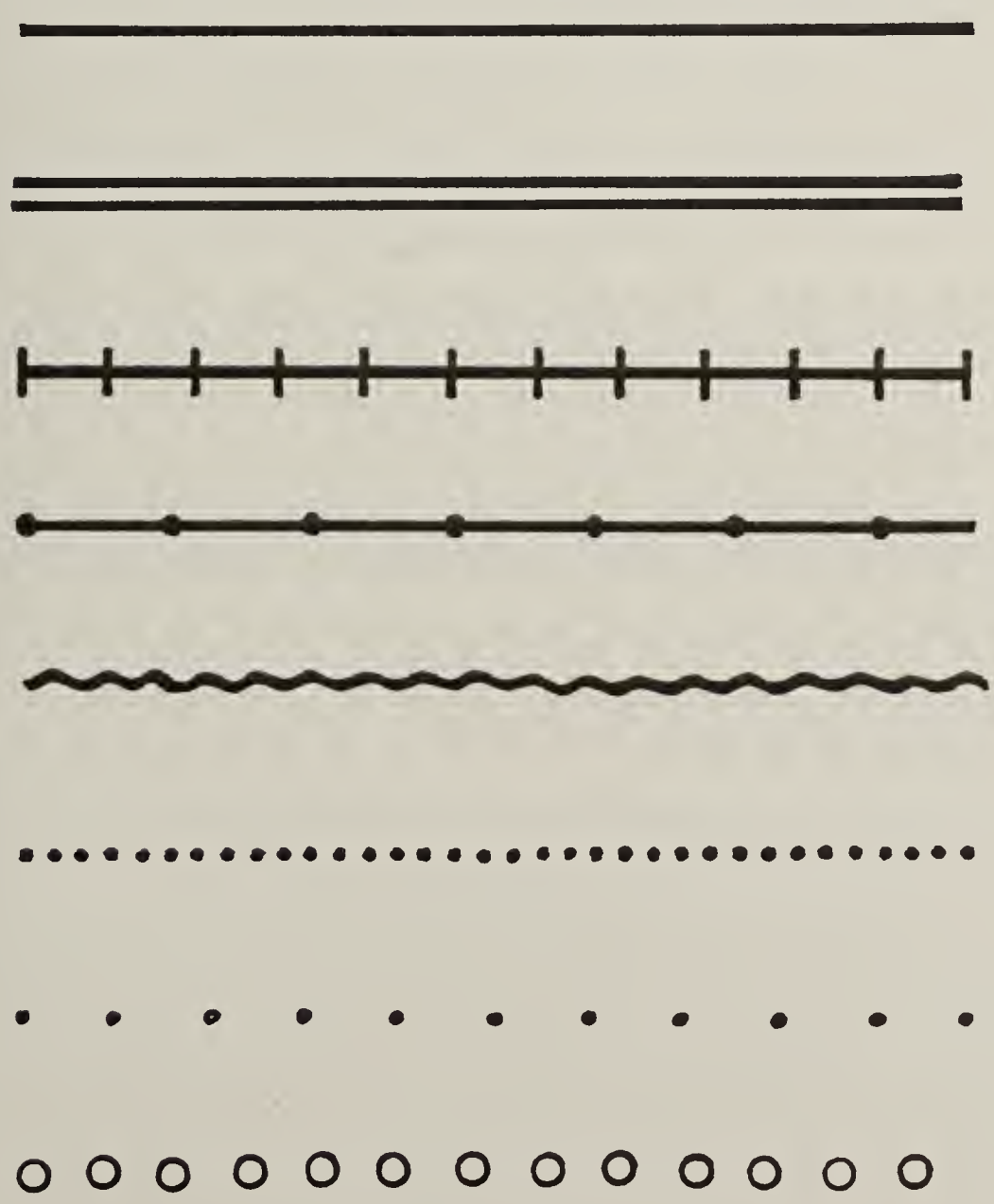
or



- complex lines consisting of different symbols in the same line; such lines are difficult to distinguish, separately or together.



Most of the following line symbols, tested by Berlin and Nyman (1971) and by Jansson (1973) in the same size as they are presented here, work well together. Lines 1, 2, and 6 are most easily discernible. Lines 4 and 7 could be confusing if used together. Lines marked with an asterisk are recommended.



1.*

2.*

3.

4.*

5.

6.*

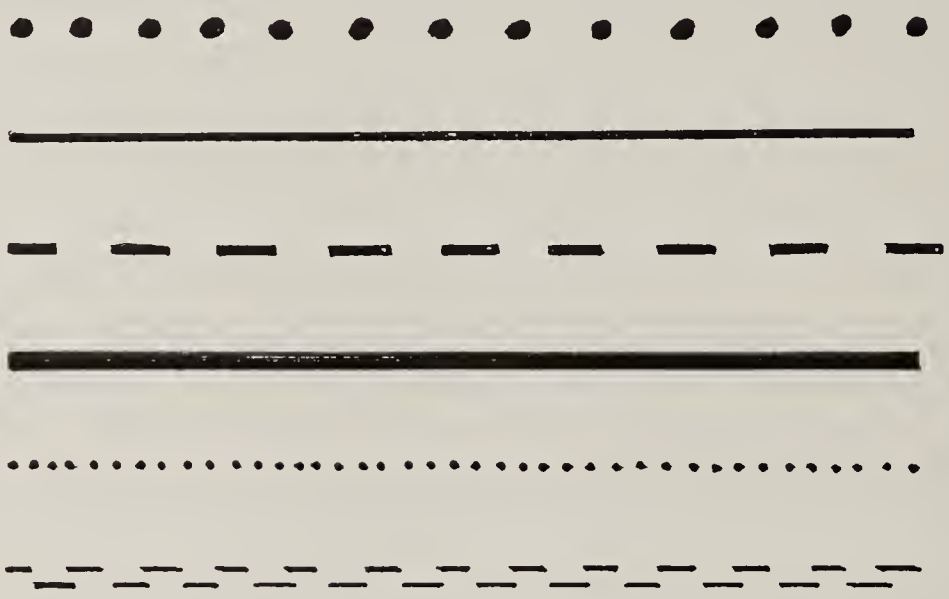
7.

8.

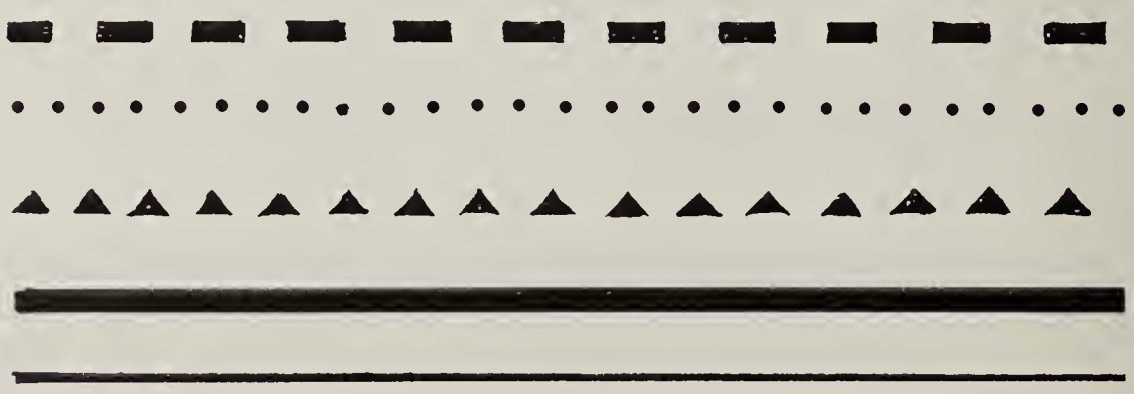
9.

*10.

The following line symbols are not easily confused if used together:

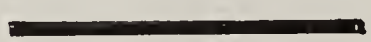
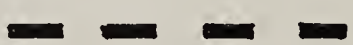


The following line symbols work well on microcapsule paper:



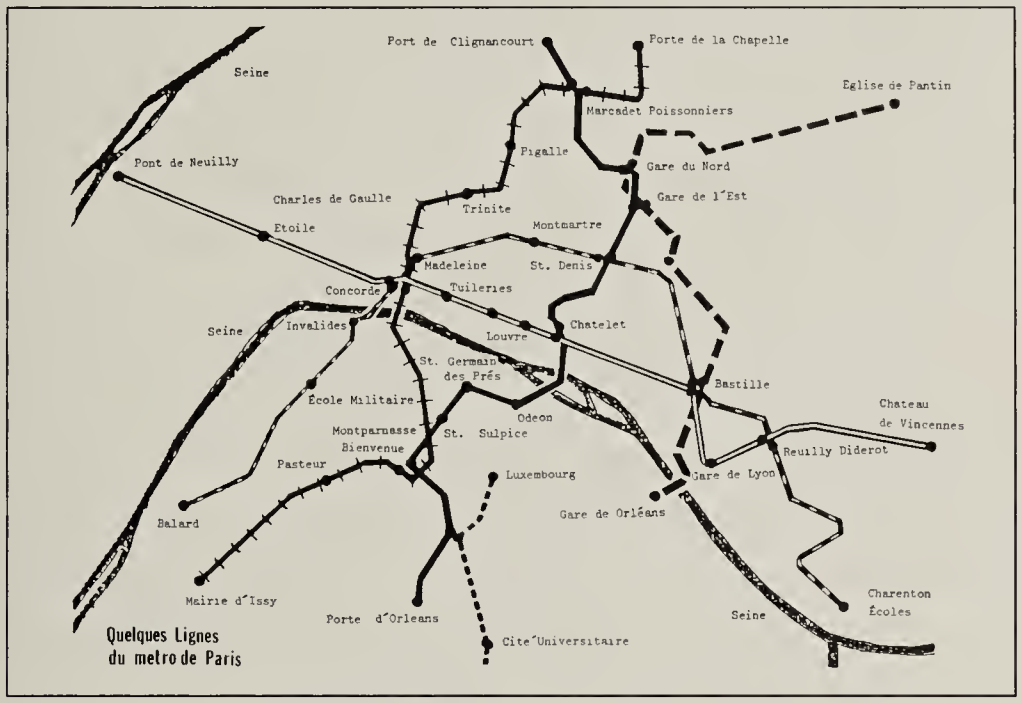
These lines do not:

or

If  and  are used in the same microcapsule display, be sure that the distance between the dashes is enough for the reader to understand that a punctuated line and not a solid line is being used.

The results of several tests indicate that narrow single lines, smooth fine punctuated lines (20 dots to 1 in. (2.5 cm)), and coarse punctuated lines (5 dots to 1 in. (2.5 cm)) can be used together on a tactile graphic display with minimal confusion to the reader.

There are many opinions among both sighted and blind people about the use of lines. The choice of suitable lines is up to you. For the best results, test your tactile graphic displays on your visually impaired readers before final production; but first, examine the lines yourself. If it is difficult for you to stay on one line, then how can your readers do so?



The importance of a variety of lines for reader comprehension is seen in this map of the Metro system in Paris for sighted travelers.

Lines can be made in many different ways. You can use:

- various types and sizes of spur wheels and freehand drawing styli (see "Embossed Paper Displays," Chapter 2),
- string and thread of varying coarseness and texture (see "Paper Buildup Displays Using Additional Materials," Chapter 2),
- sewing-machine stitching (see "Embossed Paper Displays," Chapter 2),
- cardboard, paper, and sandpaper strips,
- tapes of various widths, thicknesses, and textures (see "Paper and Tape Maps and Charts," Chapter 2),
- pipe cleaners; also, wire, metal stripping, and solder (see "Paper Buildup Displays Using Additional Materials," Chapter 2),
- staples; also, metal and plastic screening cut into strips (see

"Paper Buildup Displays Using Additional Materials," Chapter 2),

- contour paste or glue,
- inking pens, felt-tipped pens, or dry ballpoint pens,
- dry-transfer lines of various types, widths, and patterns, or
- a screwdriver pressed into the paper or foil at definite intervals (different types of screwdrivers produce various dashed lines).

Distance, Length, and Size

A line—or any other type of symbol—should have a minimum distance of .09 in. to .12 in. (2.3 mm to 3 mm) between it and another symbol. Lines separated by less than .24 in. (6 mm) tend to feel like one wide line instead of two separate lines. The minimum length of a recognizable line is .5 in. to 1 in. (12.7 mm to 25.4 mm), depending on the pattern of the symbol (Nolan & Morris, 1971). However, this minimum length does not apply to the dashes in a broken line.

The spacing between dots in a line distinguishes one dotted line from another, but the spacing between dashes in a line is not a distinguishing characteristic (James & Gill, 1975). Short lines should be made up of closely spaced small symbols—dots, dashes, and the like. Recognition of the line depends on the number of symbols in the line and the amount of uncluttered space bordering the line. Lines that are in the same area but not related to each other should be completely different to the touch.

In a "psycho-physical" experiment using constant stimuli with blind children, Berlá and Murr (1975) worked out a formula for the tactile discrimination of line width. The values could be used to determine mathematically the smallest differences that were discernible by blind children 90 percent of the time. On the average, a line had to be approximately 25 percent wider than a comparative line in order for 90 percent of the blind students to be able to recognize the difference. If one line is .30 in. (.76 cm) in width, a wider line would be .30 in. (.76 cm) x .25 = .075 in. (.19 cm) + .30 in. (.76 cm) = .38 in. (.96 cm).

Elevation

The attention of sighted map readers is gained through a variety of colors, contrasting type sizes and styles, and the

boldness of particular lines. The attention of blind readers must be gained through touch—through texture, elevation, and width of lines. The rougher the line texture and the more elevated the line, the quicker it will be noticed. It should also be noted that at the Louisville Workshop on tangible graphics held in March 1979, a group of blind examiners who inspected the tactile graphic displays stated: "When precise tracking of lines is required, line symbols should be highly embossed (about 1 mm [.04 in.]) and should have steep sides; steepness (sharpness) was considered even more important than elevation" (Schiff, 1982, p. 445).

It is easier to recognize a line symbol that is higher in elevation than the areal symbols used on the same map. It is, however, not possible to achieve this height on a microcapsule map or on other displays having only one elevation. On those maps, the distance between symbols must be increased, since all symbols are the same height. The white space adjacent to the lines should also be enlarged to allow the finger to adapt from one surface to another. The most important line should have priority; other lines crossing it should be stopped shortly before reaching the outer edges of the main line, leaving a small white space between the two areas to facilitate tracking the main line, as in the lines shown on this page.

There are also times when an important line must be interrupted. On a microcapsule map, for example, the borderline of a country may have to stop for a coastal city.

Structure

The greatest contrast between adjacent lines is gained more from the difference in texture and width than from elevation. Lines that cross other line symbols are easier to recognize if the structure of the individual lines differs widely from one another. (This applies also to the various widths of the lines.)

A rough, sharp line will be more noticeable and thus more important to a visually impaired reader than a smooth line of the same size. Opinions vary on the speed and accuracy with which readers can trace a rough line and a smooth line. It seems that the difference depends on how the line is presented.

Dotted and Dashed Lines

Broken lines are thought to be more easily traced than smooth lines. A single, narrow dotted line of approximately 20 raised dots per 1 in. (2.5 cm) was found to be the most rapidly and accurately traced type of line in tests made in 1968 (Angwin, 1968a, 1968b).

With dotted and dashed lines, the reader should be able to feel the second dot or dash before leaving the first one, if the line is to feel continuous. Dashed lines used to indicate boundaries should always remain just that—a dashed line. The dashes should not change character and become curves in tight areas. They should always be straight lines with a uniform space between each dash. By changing character, the curved dashes shown on this page become another symbol to the map reader.

The spaces between dashes in a dashed line should be of such a length that it is not possible for the reader to confuse the line with a solid line. This is especially important in microcapsule paper displays. Experiment and test dashed lines before making a final display. The suggested length and spacing of a broken line: dashes 1/4 in. (6 mm) to 3/8 in. (9 mm), spaces in between the dashes approximately half as long as the dashes.

Lines symbolizing latitude, longitude, and the equator should be of such a character that they are not taken as an integral part of a country. Their dominance through size and texture should be determined by their importance in the map. Lines chosen for this purpose should be kept the same throughout a map series, as in an atlas or in a step-by-step presentation.

Broad vs. Narrow Lines

Readers can trace a broad raised-line contour of a figure or an area without being distracted by intersecting lines of a smaller dimension or another texture. This is especially true in one-elevation relief displays.

Here, again, opinions differ. A test of tactile political maps conducted by Berlá and Butterfield (1977) asked the participants to recognize the shape of figures enclosed by wide raised lines, 1/4 in. (.63 cm); by narrow raised lines, 1/16 in. (.16

cm); or within a furrow, 1/4 in. (.63 cm). The result was that readers traced the wide raised lines with the greatest speed and accuracy without becoming distracted by intersecting lines.

But another group of tests, conducted by Bentzen (1983), concluded that narrow single lines usually function better than or as well as wide single lines, narrow double lines, or wide double lines for tasks that require perception and memory of the arrangement of the parts where lines intersect.

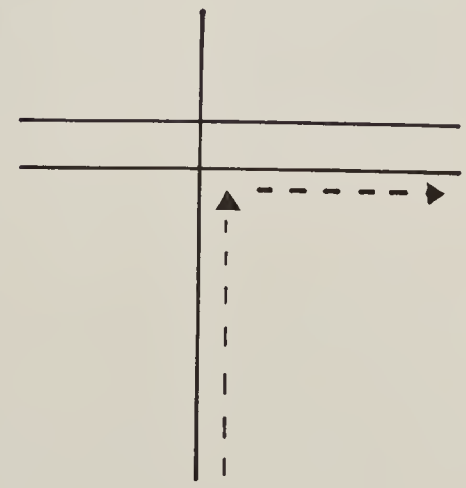
Both conclusions can be right. The tests may have been made under different conditions, with different age groups and other factors. The point is that at present you must rely on your experience and judgment and on the requirements of your particular display. On a public transportation map made by Hendrik Vlaanderen of Amsterdam, Holland, the routes were represented by lines of varied thickness, depending on the frequency with which the different routes were used.

Single Lines or Double Lines?

In tests of single and double lines (see Bentzen, 1983), single lines give rise to more accurate mental images than do double lines, especially in relatively complex displays. Single lines were also traced faster and with greater accuracy than were double lines. The distance between the double lines was .25 in. (.64 cm).

In addition, single lines occupy less space than double lines. The overall size and scale of a map can be smaller if single lines are used rather than double lines. This is true in the production of general orientation maps at a scale of 1:5,000. The space is limited on smaller scale maps, and using single lines may help to prevent overcrowding.

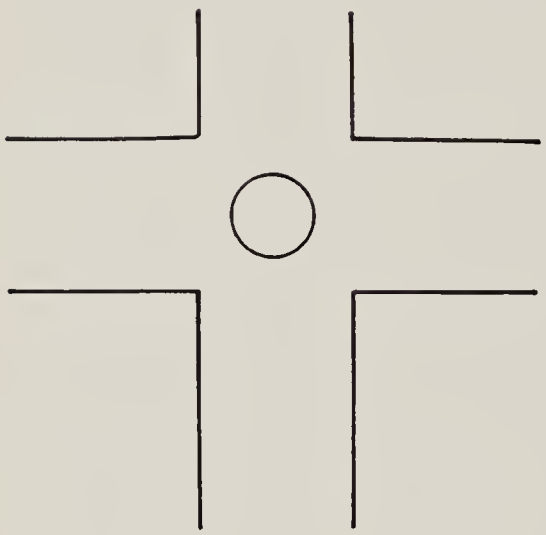
Avoid having a single line and a double line cross each other. If the reader is tracing the single line and comes to the crossing, he or she does not continue across the intersection but rather turns right along one line of the double lines, thinking that he or she is still tracing the original line.



Some teachers have said that young children prefer , whereas older students and adults prefer . I would say

that it depends on the type of map and the capabilities of the readers.

With double lines, the speed and accuracy of line tracing are greatest when the double line is in the form of a track or furrow having parallel edges .20 in. to .25 in. (.50 to .63 cm) apart. Wide double lines, in contrast to narrow double lines, do not function well as a furrow (see Amendola, 1976). They require more space in a tactile graphic display, slow down the reader's rate of extracting information, and contribute to inferior spatial memory, especially when complex intersections are encountered (see Bentzen, 1983).



Even through double lines are more literal representations of routes on mobility maps, they are unnecessary, unless the user has difficulty envisioning an environmental feature with two important sides, such as a street, from a single raised line or unless there are particular environmental constructions that cannot be portrayed accurately enough for some purpose without using double lines. Information concerning the placement of an island in the center of an intersection is a good example of this. Discussion of the traffic pattern is easier for the map reader to understand on a double-line intersection than on a single-line intersection, as in the illustration shown here.

AREAL SYMBOLS

Areal symbols represent a bird's-eye view of particular areas on a map. They indicate the area's shape, size, and location. Several areas of the same texture may appear on a map. Although the shapes and sizes of these areas may vary, the information they give is the same. They may indicate elements like the amount of rainfall, particular vegetation, migration of peoples, park areas, buildings, or water.

Texture in an area helps the reader quickly identify and understand the limits of the area. Without texture, the reader may have difficulty tracing the outline of an area and deciding which of several areas he or she is actually touching. It should be noted here that the roughest texture in a display attracts the most attention and becomes more important than the other areas.

Areal symbols are not confined to map production. They

are as important in the construction of pictures and graphs as are the other symbols mentioned in this discussion.

Variation in areal symbols can be gained by:

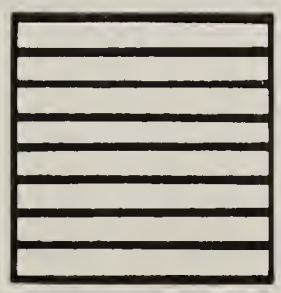
- the degree of organization in the pattern, for example, whether it is evenly spaced or irregularly spaced,
- the density of the pattern (the space between the elements and the number of elements within the space),
- the profile of the elements (rough or smooth),
- the form or shape of the elements,
- the size of the elements, or
- the direction of the pattern (vertical, horizontal, or diagonal).

Textured areas can be made with various embossing tools (see "Embossed Paper Displays," Chapter 2); metal, plastic, or cloth screening; cloth materials; sandpaper; cork; wood; string; structured cardboard; sewing machines; bookbinders' weave; wallpaper; and so on. Various textures produced with embossing tools or spur wheels have a surface that is similar to certain grades of sandpaper. Consequently, do not use these textures together with sandpaper in the same display.

The following symbols were the symbols used in Nolan and Morris's 1963 studies of textures. The symbols portrayed are one-half the size of those used in the studies. The dimensions of the patterns themselves are not altered. Recommended symbols are marked with an asterisk.

Continuous straight lines:

*



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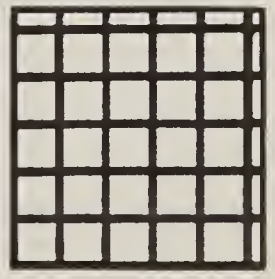
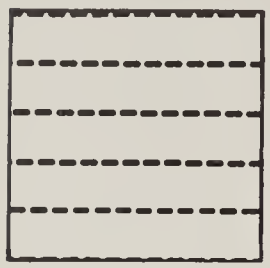


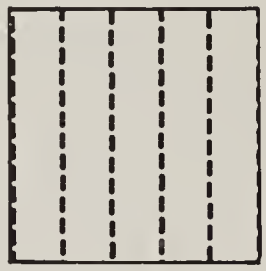
*

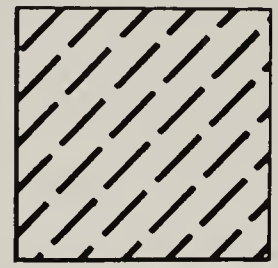
Continuous curved lines:

*

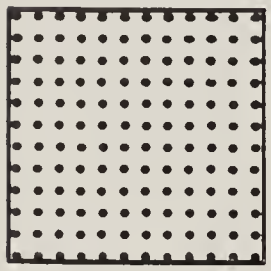
Broken lines:

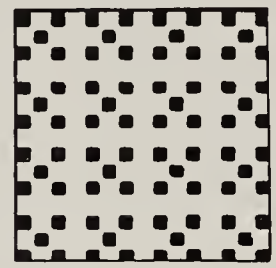


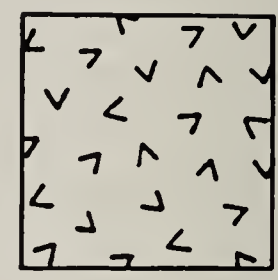




Patterns consisting of smaller units:

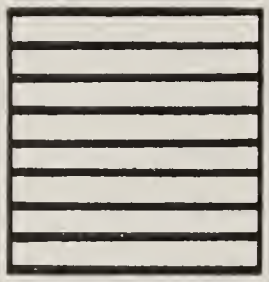




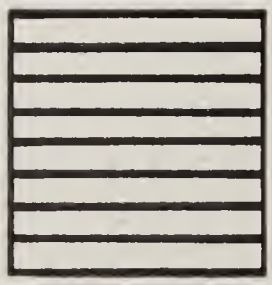


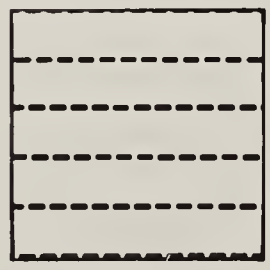
Nolan and Morris (1971) found that the following types of areal symbols are often confused if used together.

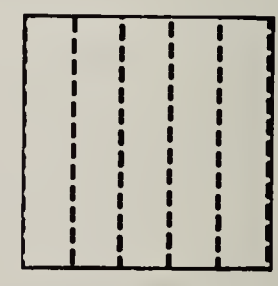
Symbols consisting of straight lines with different directions:



Symbols of continuous straight lines and dashed lines, with little space between the dashes:

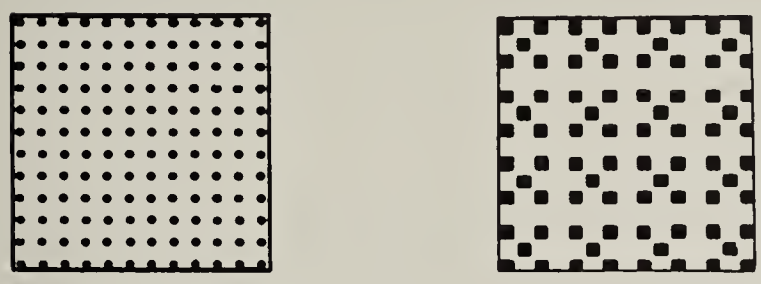




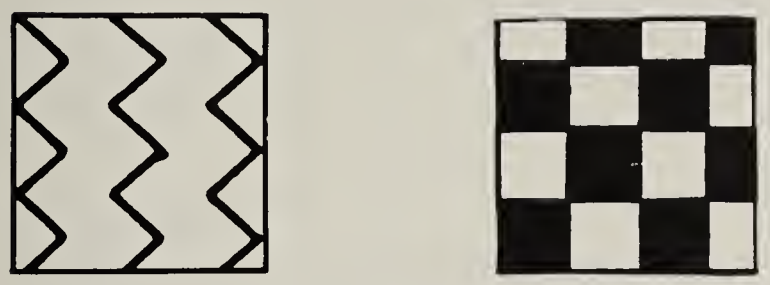


Symbols with continuous straight lines and slightly curved lines:

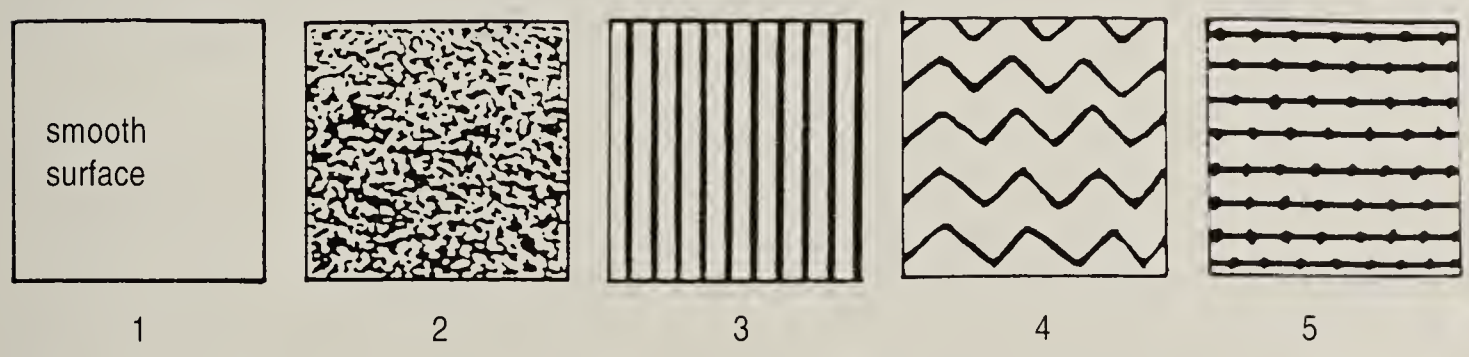
Similar patterns made up of different forms:



Symbols with similar contours:



These areal symbols were studied in Jansson's 1973 experiments:

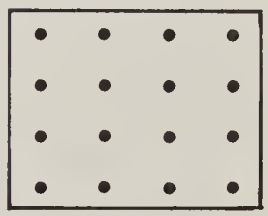


Rigorous testing proved that textures 1, 2, 3, 4, and 5 are the best combination of areal symbols for a display.

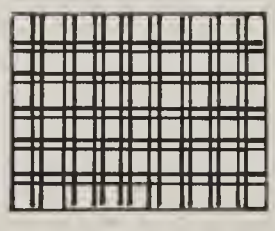
The materials used in Jansson's areal symbols, keyed to the numbers of Jansson's symbols shown on the previous page, are as follows:

1. Smooth cardboard with no extra texture.
2. Sandpaper, grade 5.
3. Cardboard with waxed machine thread 18/6. The distance between the centers of the lines is 3/32 in. (2.4 mm). A thin layer of glue was applied to the cardboard, and the strips are held in a parallel position by small slits in the edge of the cardboard.
4. Cardboard with a zigzag sewing-machine pattern, sewn with 3-ply linen thread. The distance between the "top and the valley" of the design is 1/8 in. (3 mm). The distance between the two tips is 5/16 in. (8 mm). The distance between two rows of stitching is 1/4 in. (6 mm).
5. Cardboard with knotted thread. The distance between knots is 3/16 in. (5 mm). The distance between threads is 3/16 in. (5 mm).
6. Cardboard with parallel leather strips 1/8 in. (3 mm) wide and 1/16 in. (1.6 mm) thick. The distance between strips is 1/8 in. (3 mm).
7. Cardboard 1/32 in. (1 mm) thick. The pattern of dots is made with a large spur wheel; the distance between dots is 1/16 in. (1.6 mm).
8. Repeat pattern of a cross, 3/8 in. by 3/8 in. (9 mm by 9 mm). A relief master made from a black-ink pattern printed on cardboard. Elevation: 1/32 in. (1 mm).

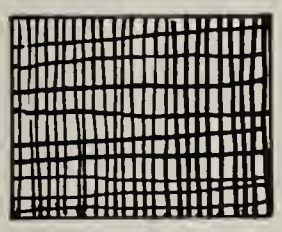
The following are additional textures. (There are many more than those mentioned here. Experiment yourself!)



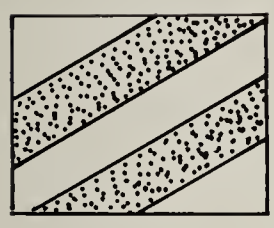
A repeat of the letter K on the braillewriter.



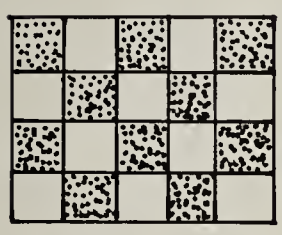
Embroidery canvas with an even distance between the threads (used as a water symbol in vacuum-formed maps in Scandinavia).



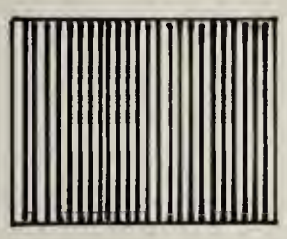
Bookbinders' weave—an uneven thread structure (often used as background material in displays; see "Embroidery Canvas and Bookbinders' Weave," Chapter 2).



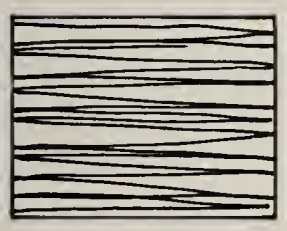
Various sandpaper patterns glued on smooth cardboard. (Sandpaper comes in many grades of coarseness.)



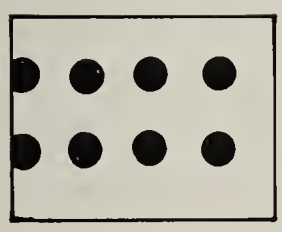
A sandpaper pattern that can be made with a number of different materials.



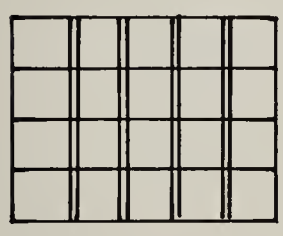
Fine or coarse corduroy or fine-lined corrugated cardboard and corrugated paper, as found in candy or cookie boxes.



Crepe paper glued on paper or cardboard (this has been used in Europe as a symbol for water).



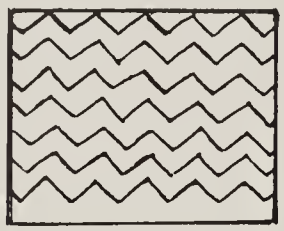
Cardboard dots produced by a hand punch for paper or leather and glued on a smooth surface, or dots embossed with a jumbo freehand drawing stylus.

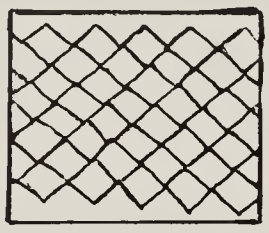


Thin curtain material that offers a wide variety of textures.

Making Patterns and Textures

Patterns made on a sewing machine are easy to do and add to the variety of embossed textures. Another advantage is that a large area of texture can be made quickly at one time.





Patterns can be made directly on the background material or on a sheet of paper and cut to fit the desired area on the map. They can be made on a sewing machine easily, and doing so adds to the possible variety of embossed textures.

Patterns can be made by cutting strips of paper with a pinking shears—a special scissors often used in dressmaking. Braillewriter paper is excellent for this use. Glue the strips layer upon layer to get the desired effect, such as the ones shown here.

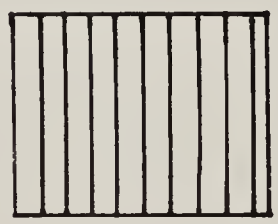
When making textures on separate sheets of paper, cardboard, or cloth material, make more than you need at that moment. Two types of textures that can be made in large quantities are dots and stairs.

Raised dots of all sizes for use on pictures, maps, and diagrams can be made of cotton blue jeanlike material, which is soaked with glue and pressed onto another piece of thin cotton material, such as cotton bed linen, and allowed to dry under pressure. Because this material has already been saturated with glue, which keeps it from absorbing more glue when mounted on the display, it will have maximum adhesion for even the smallest dot.

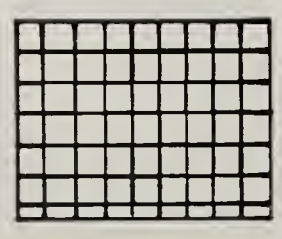
Stairs can be made of heavy thread, preglued, mounted on paper and cut into strips. One sheet of threads can supply an unbelievable number of stairs of varying sizes.

Textures for One-Elevation Relief Displays

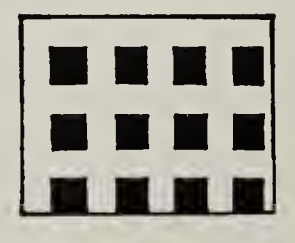
Some areal textures can be confused if used together on one-elevation maps or pictures embossed or produced on microcapsule paper. Textures (see A and B) can feel the same, although they appear different to the eye.



A.



B.



C.

It was necessary to change the checkered texture B to a small squared pattern C to achieve a contrasting surface that could be used with texture A.

Always test textures with your fingers. A texture can be

drastically altered to the touch by changing the scale of the pattern. Lines or symbols moved closer together or farther apart or made thicker or thinner can totally change the feel of the design. If you keep an active file of textures as you progress in your work, the choice of suitable textures will become easier with time and practice.

The microcapsule paper map illustrated below is an example of the absolute maximum number of textures in one display. I would prefer only five textures as a maximum number in almost all types of displays that use the production methods that are currently available.

A microcapsule paper map in which many different textures need to be distinguished by the reader.

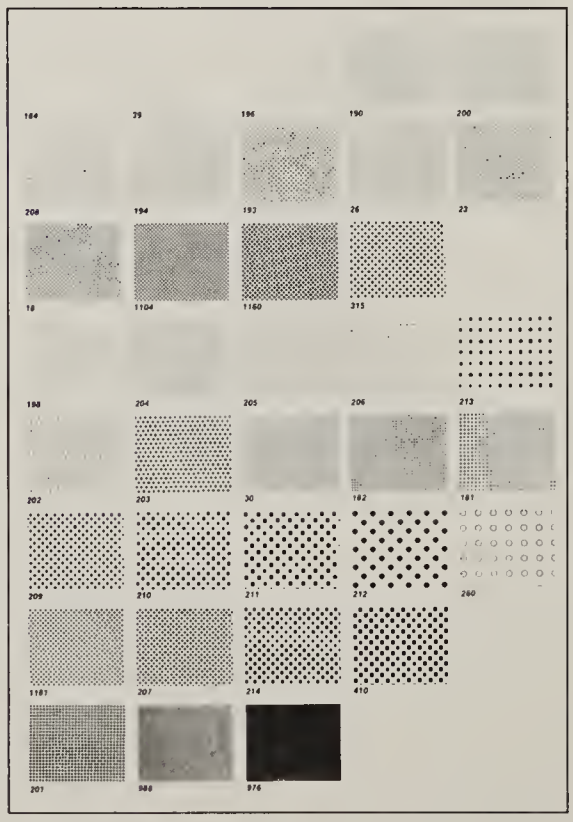
The number of textures that can be used together depends on the character of the various textures in the display. Can the reader locate and understand the meaning of the different areas? Although advanced map readers could locate the different areas on the map shown here, it was not an easy task. The texture used along the western coast of the United States is not a good choice for use with the texture covering the midwestern area. They are identical in character; it is only the

angle of placement that differs. When swelled, the dense texture of Central America felt similar to the solid black area used for the eastern part of the United States. This is to be expected, since both areas give a feeling of solidity. A lighter, more open texture should have been used.

Large areas of black are to be avoided if possible. In this map of North and Central America, the producer was forced to use solid black because the selection of compatible textures was limited. There were not enough different designs for one-elevation use to supply the necessary information. Perhaps several maps would have presented this information in a better way.

Commercial Textures for Microcapsule Paper Displays

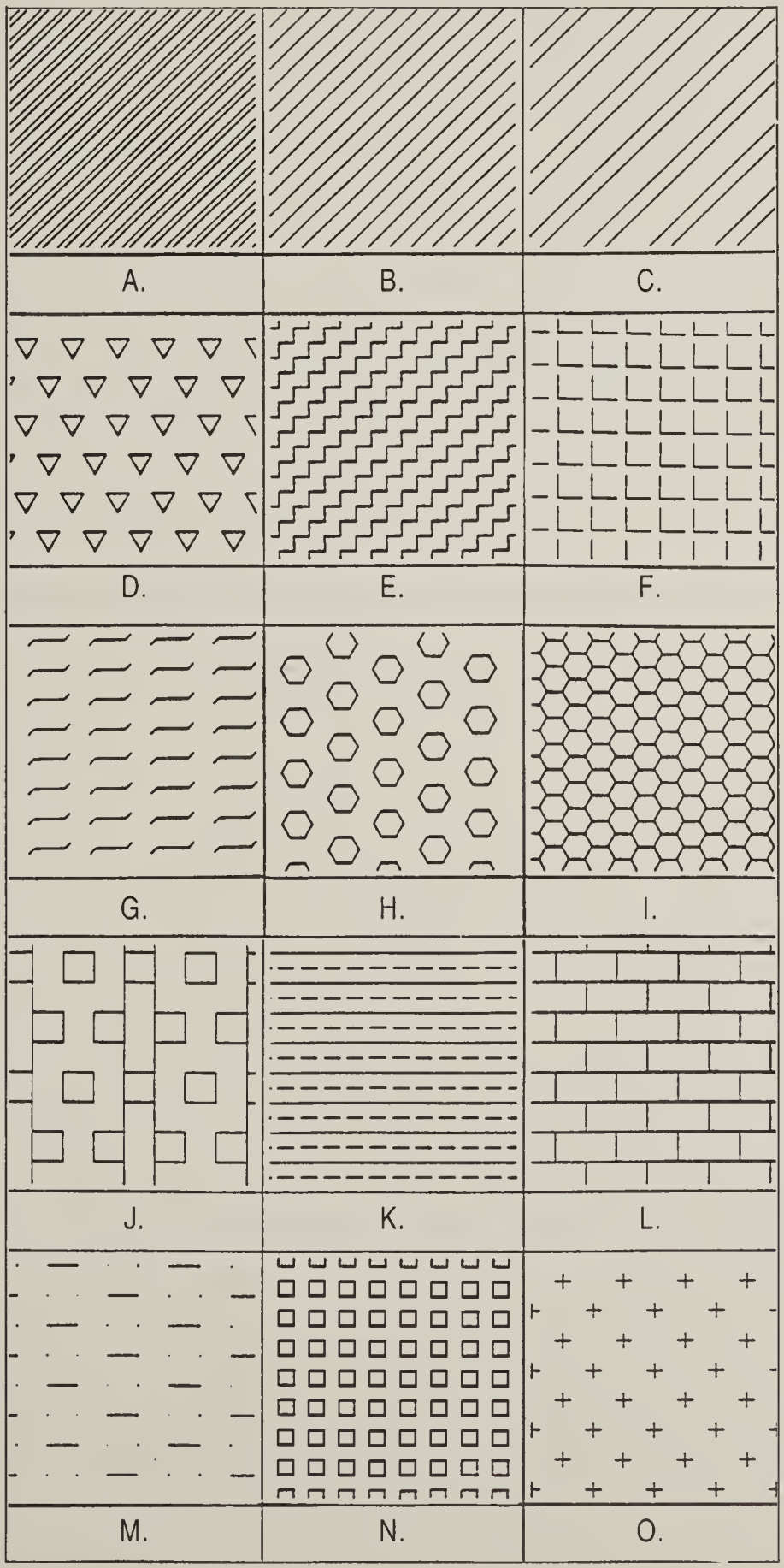
Instant dry-transfer patterns are produced by several manufacturers. The only way to tell whether the different textures can be used on a relief display is to make a microcapsule paper copy of pattern pages from a catalog, like the one shown below. It may be necessary to increase the size of the patterns on the sample page to be able to reach any conclusions about their usefulness in relief. The scale of the patterns in the catalog has been determined for the sighted public. Swell the microcapsule paper copy and test the results with your fingers only. This test will eliminate many of the patterns, and those that are interesting can be purchased for further testing and use.



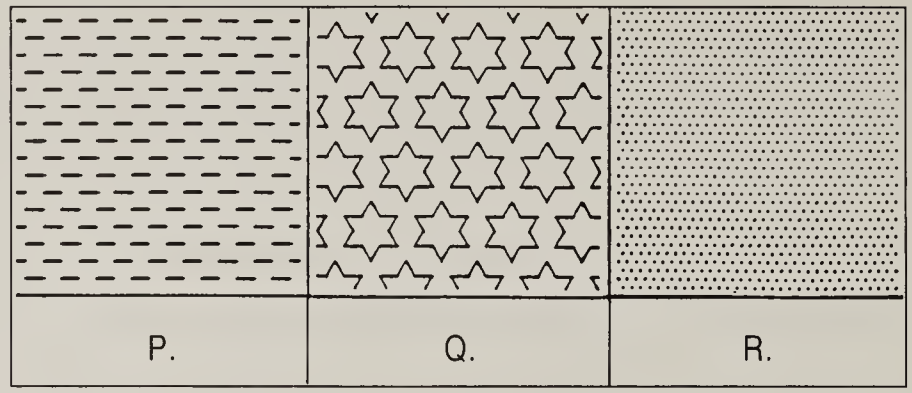
A catalog page of instant dry-transfer graphic textures (*Mecanorma Graphic Book*, 1986).

Computer Textures

Today, it is technically possible to produce textured designs for blind persons on a computer. However, these textures have not been tested to any extent. When the designs shown below were produced on microcapsule paper, it became obvious that E and I were impossible to differentiate, and A and B were difficult, as were F and I. Relief patterns of all types must be finger tested by the visually impaired reader to be acceptable for tactile graphic displays.



Automatic computer-aided designs.



Size

Tactile areal symbols with outer dimensions of 2 in. by 2 in. (51 mm by 51 mm) are easy for blind readers to discriminate. Symbols with outer dimensions as small as .8 in. (20 mm) are often discernible. However, areas smaller than .5 in. (13 mm) are difficult to feel (see Nolan & Morris, 1963).

The minimum-maximum size of a design texture within an areal pattern is difficult to state because each areal pattern is determined individually, according to the needs of a particular display. The best way to find the right scale for your texture is to test different relief patterns on your visually impaired readers. It is apparent that older children are able to discriminate more patterns of smaller sizes than are younger children.

Each areal pattern used in the same display should have a distinct character. No two patterns should be so similar to the touch that they confuse the reader.

Choice of Pattern

The choice of pattern for a textured area depends on the other symbols that will be included in the same area. If a line (or lines) cross the area, choose a solid pattern for dotted lines, a dotted pattern for solid lines, and so on. Both line and point symbols within the same area confine the choice of texture. Sandpaper of different grades of coarseness is often a solution.

Important areas of information should be indicated by roughness. Rough areas attract more attention more readily than do smooth areas. When two or more textures appear in the same display, the heavier, rougher texture is reserved for the more important areas. Elevating an area above its surroundings will also increase its importance.

A line defining the outer edge of a textured area is useful when several textured areas are placed next to each other. It

makes it easier for the reader to differentiate the areas. This system is especially useful on one-elevation maps or diagrams. Remember to leave a 1/8 in. (3 mm) blank area along the line adjacent to each textured area.

Elevation

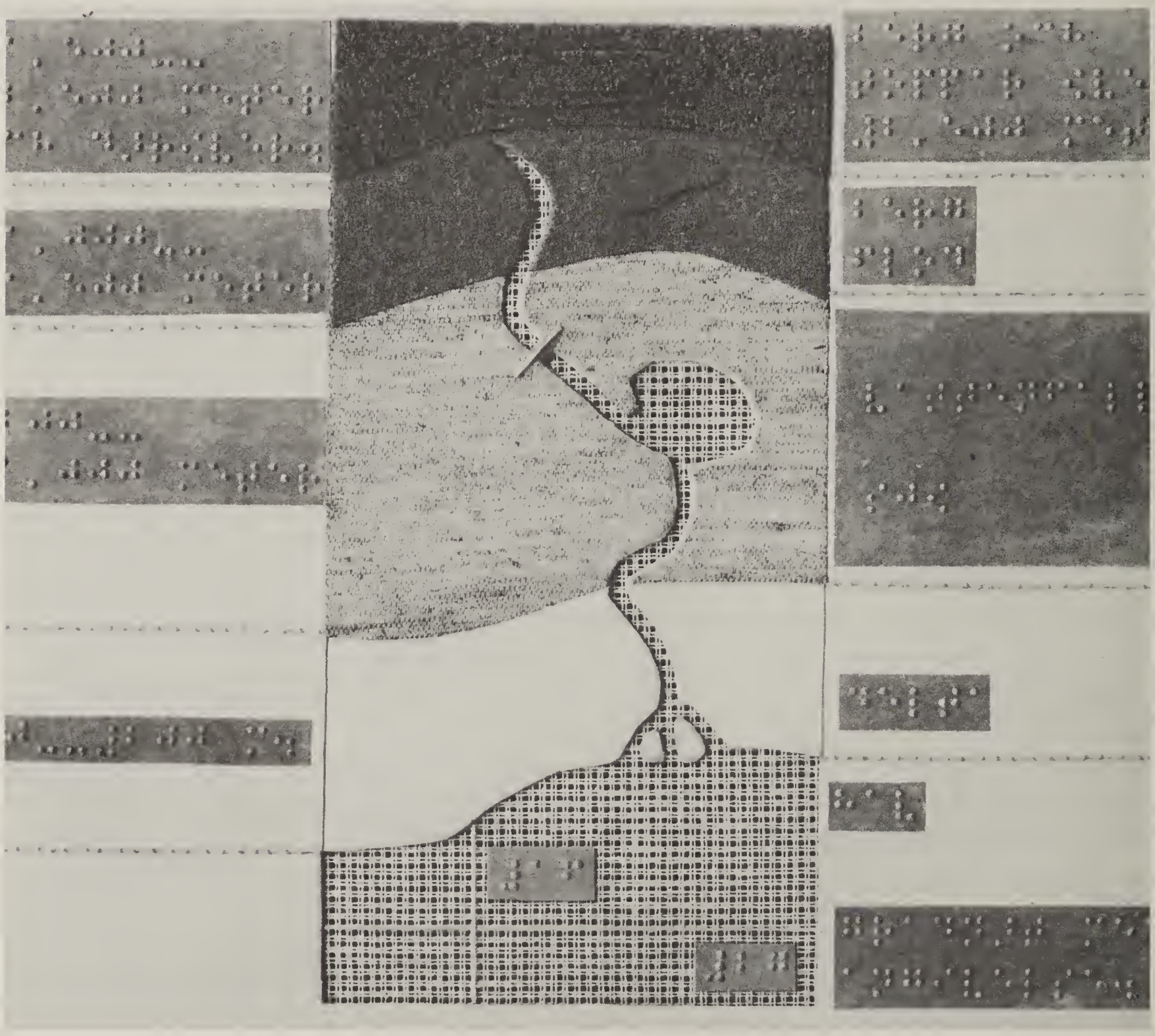
The height of areal patterns should be kept at a minimum when point, line, or braille symbols occur on the same display.

Point, line, and braille symbols can easily be lost within a textured area. To remedy this, provide less elevation to the areal pattern or more elevation to the other symbols and more white space around the point, line, or braille symbols. Be sure that the symbols are not too similar to the area texture in form, layout, or structure. Change the scale or pattern of the textured area. These points are applicable to displays of several elevations or one-elevation. However, since the one-elevation displays cannot vary the elevation of the various symbols, it is advisable to increase the white areas adjacent to the symbols within the textured area.

An Attempt at Standardization

According to an agreement made in 1965 by a Scandinavian map committee consisting of members from Denmark, Finland, Norway, and Sweden, an atlas would be produced for teaching geography to blind people. This is one of the earliest known attempts to standardize map material for visually impaired people. This atlas, *Nordisk Atlas för Blinda*, was produced by RPH-SYN, the National Center for Educational Aids for the Blind, in Solna, Sweden, in 1966. Four different textures were used to indicate height over sea level. Embroidery canvas symbolized the sea. The four textures were cardboard, for 0 to 200 meters above sea level; cotton material, for 200 to 1,000 meters above sea level; fine-grained sandpaper, for 1,000 to 1,500 meters above sea level; and coarse-grained sandpaper in one, two, or three layers, for 1,500 to 2,500 meters above sea level or higher. Today a great many of these maps are obsolete, and the more recent maps produced in Scandinavia have moved away from the original idea of standardization. It has been observed that some of these textures are often confusing. How necessary is it to indicate height over sea level, considering the

amount of information already required on a map? Can this information be gained through a written or verbal description of the map or area? If this could be done, certain textures would not be locked into a definite category and could be used to fit several different needs.



An instruction page from the atlas, *Nordisk Atlas för Blinda* (1966). The surface symbols (areal symbols) represent a range from 1,500 to 2,500 meters above sea level down to sea level. The materials used are, from top to bottom, sandpaper grade 5, sandpaper grade 2, cotton material, cardboard, and embroidery canvas.

The following are some points to keep in mind when using texture:

- Be restrictive with textured areas. Their presence tends to clutter a map and increases the difficulty of locating point symbols and tracing lines. It may be better to make several maps with few areal textures than one map with many

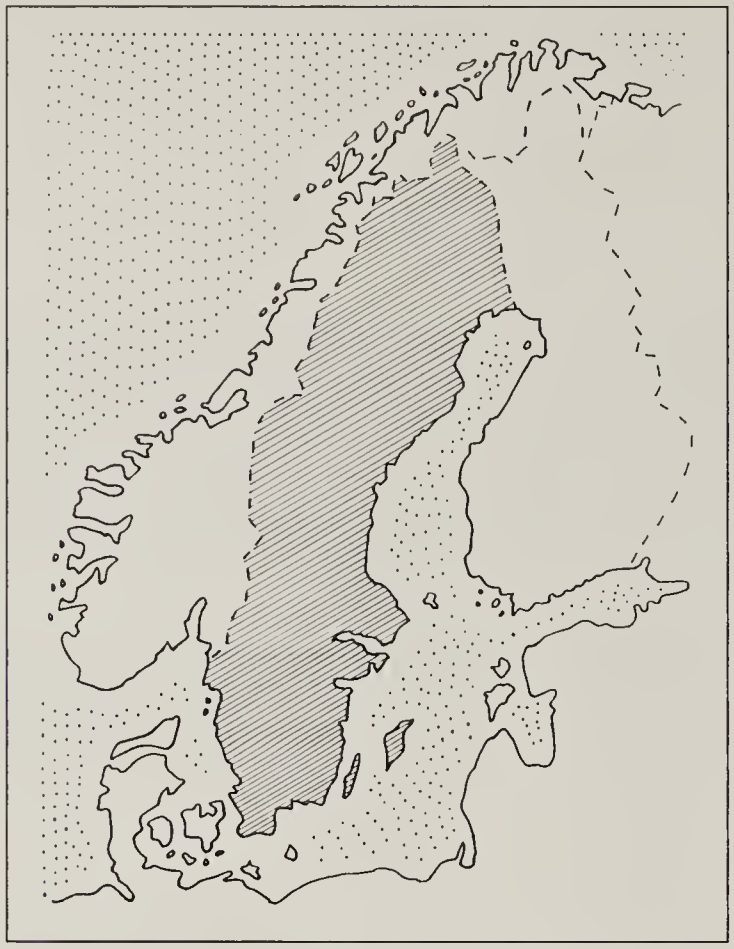
textures. A label on a particular area may be just as adequate as a texture.

- Be consistent in the choice of texture in related displays. The same texture should stand for the same information throughout a step-by-step series of displays or a series of maps depicting different countries, cities, and so on. This does not mean that the particular texture always indicates a particular type of information. The texture may be used for an entirely different purpose outside the series.
- Repeat in the key to the display all textures, with a description of the information that they represent.

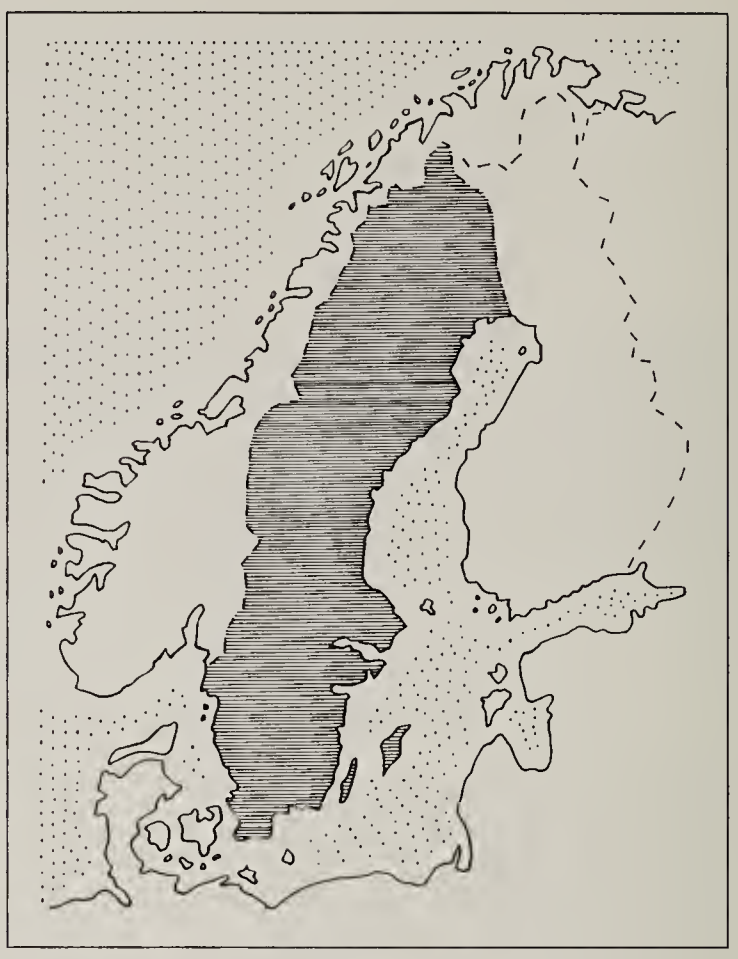
The map shown here (see A) on microcapsule paper is one of the first maps for a beginning reader. It is very simplified, showing only the area of Sweden in relation to neighboring countries. Note the white corridor between the water texture and the land texture.

A.

The two maps shown on the following page (see B and C), although similar in character, felt different to young readers. Children said that map B kept forcing their hands to shoot out of the picture in a right-diagonal direction, while the map on the right was most acceptable to them. This is a point to consider when choosing a texture for beginning readers.

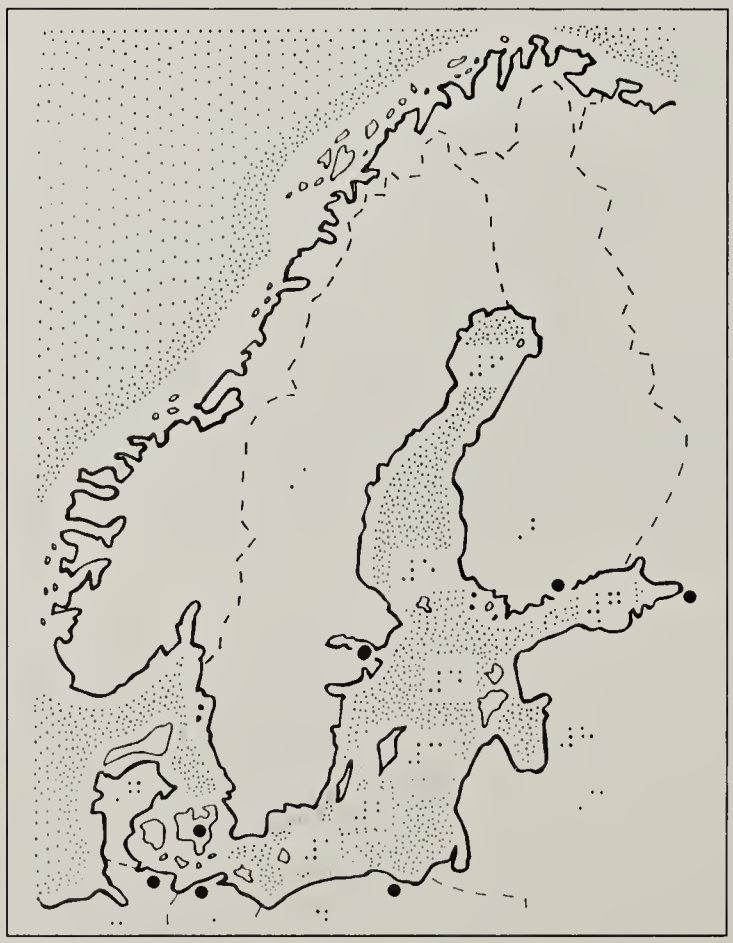


B.



C.

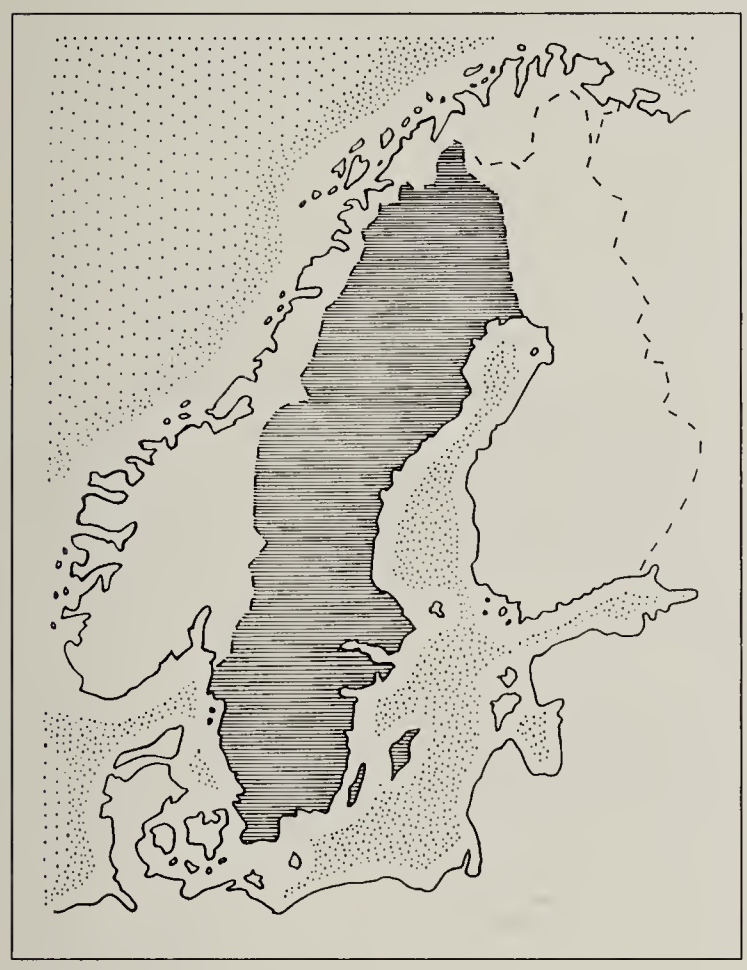
I do not advise the use of braille within a dotted area on any type of map—one elevation or several elevations. The braille could be confused as being part of the dotted pattern. However, if there is no other solution for the choice of texture or



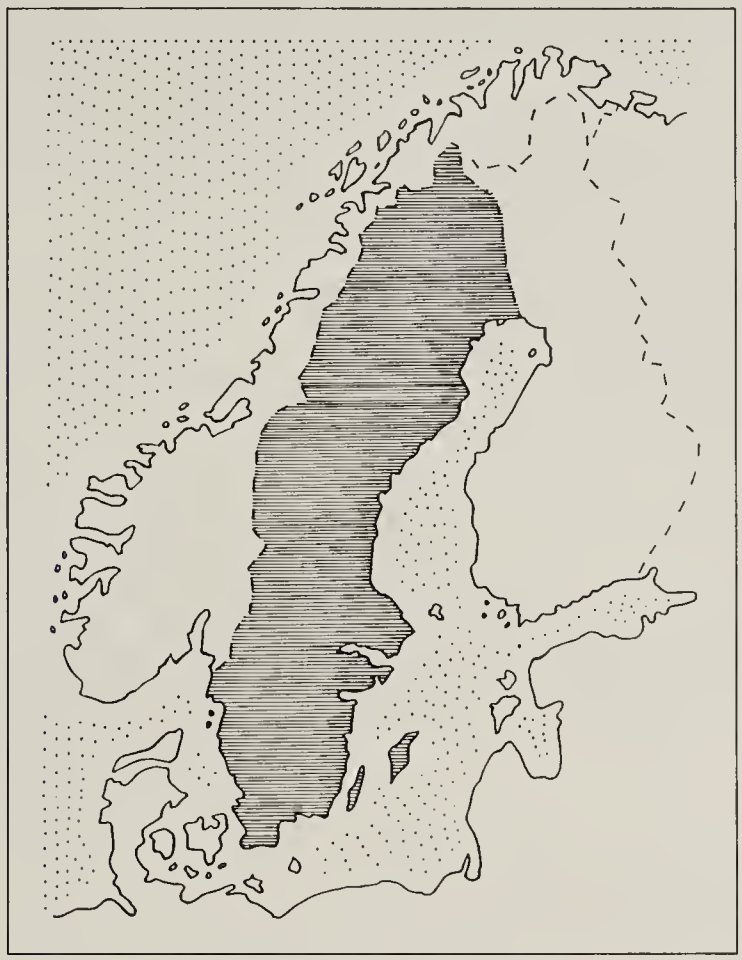
D.

the placement of symbols, I would suggest increasing the density of dots around the white area that should surround the braille character (see D on previous page). This will make it easier to locate the braille label.

Increasing the density of dots along the white corridor that separates water from land made it easier for children to follow the coastline on map E than the one on map F.



E.



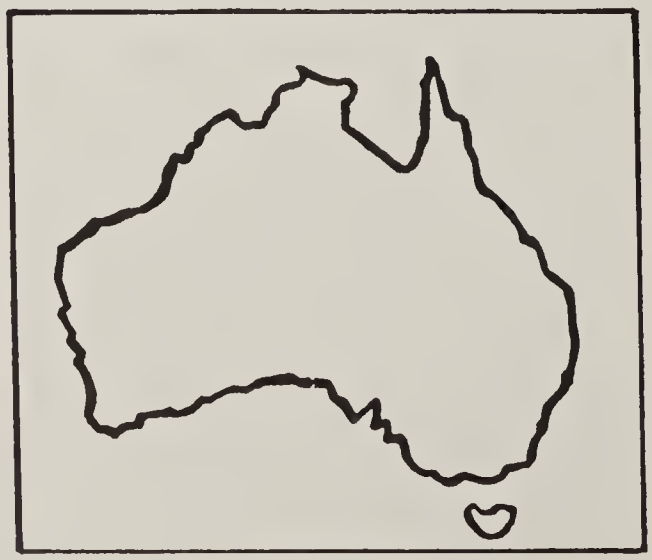
F.

The map of Europe shown on the following page, made on microcapsule paper, is for students with map-reading experience. With its lack of detail, the map gives the students an overall picture of Europe. It enables the teacher to add the information that is pertinent to particular readers, since microcapsule maps can be reswelled after information has been added with a black felt-tipped pen. The map is also useful to low vision readers; various colors can be added to the different countries with colored pens or paints.

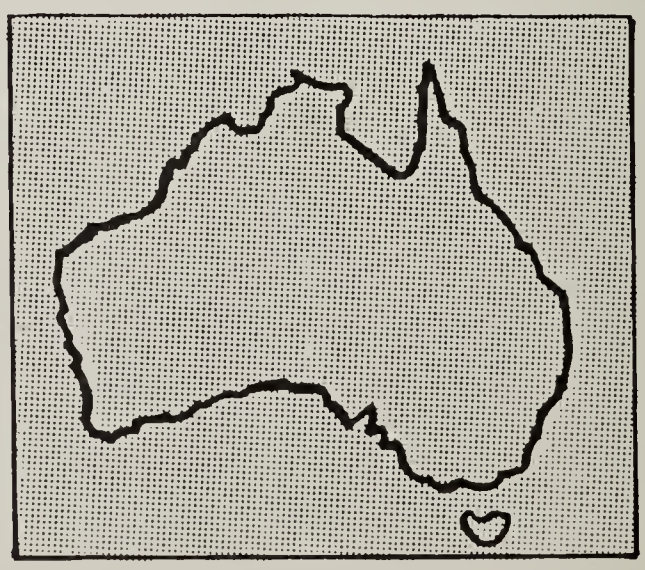
The textured water in this map and in the following examples is made from a sheet of black-and-white graphic texture, which was copied onto a sheet of white paper in an office copying machine. The original map, without water texture, was then placed in the copy machine (step 1), and the

A microcapsule map of Europe that can be adapted for low vision readers.

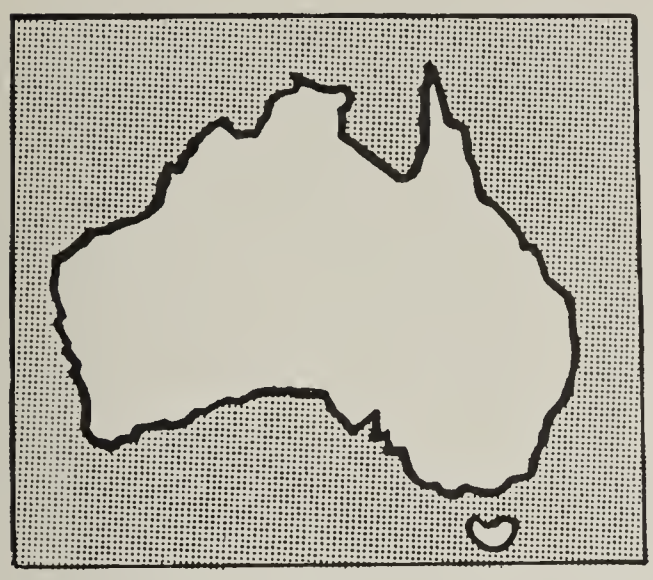
graphic texture sheet was fed through the machine. The image of the map was copied onto the graphic texture sheet (step 2). The water area of the map was then cut away with a scalpel. The textured area was sprayed on the back side with an adhesive spray and mounted on the original map (step 3). The thick black lines were then retouched.



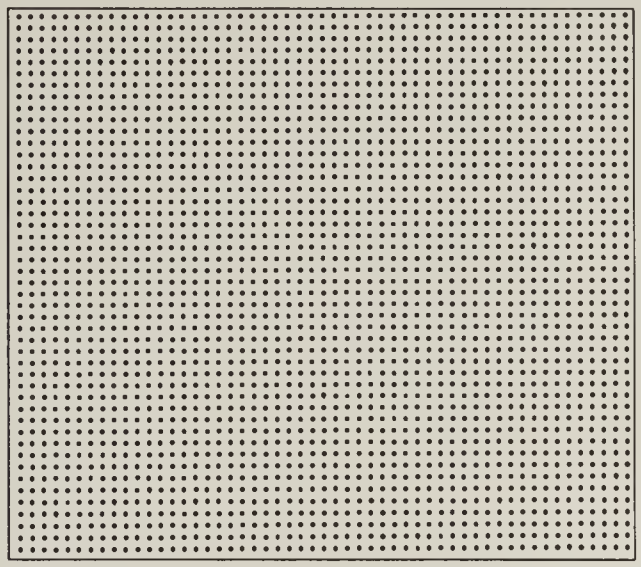
Step 1



Step 2



Step 3



Actual size of the texture sheet used on these maps.

On maps using this particular graphic texture, it is unnecessary to make a white corridor between the land and the water. The heavy black line swells up sufficiently to catch and hold the interest of the reader's finger. It is an obvious outline between a structured area and a smooth surface.

So you see, there is a solution to each situation. It may not be the same solution that you have used before, but making tactile graphics is a challenging and ever-changing occupation. It depends on the availability of different materials, old theories, and new ideas, but most of all on the information that you and your readers receive through your fingertips.

WATER

For years, the standardization of symbols has been discussed on both sides of the globe. The symbol for water has been of great interest, although no definite conclusions have been made concerning its texture. Because of different production methods, it is difficult to settle on one texture. In 1980, the Scandinavian countries tried to solve this problem. They suggested that water should have an east-west directional texture that would make map reading easier for students. They soon discovered that this suggestion limited the choice of textures to be used elsewhere in a map. The limited availability of a commercial-quality striped relief texture also made it impossible to use this suggestion. Consequently, the countries continue to use embroidery canvas for oceans and lakes on masters that are to be duplicated in the vacuum-forming process. This material is both inexpensive and readily available in most countries.

Embroidery canvas used in a map master can be mounted without gluing it to a background surface. Cut a narrow frame for the map. Glue the canvas on the back of the frame. Glue the continents and islands directly on the canvas on the same side as the frame. The holes in the canvas are an advantage in the vacuum-forming process, since they allow the plastic overlay to be sucked into the uneven surface of the master, which results in a very sharp and clean-cut plastic copy.

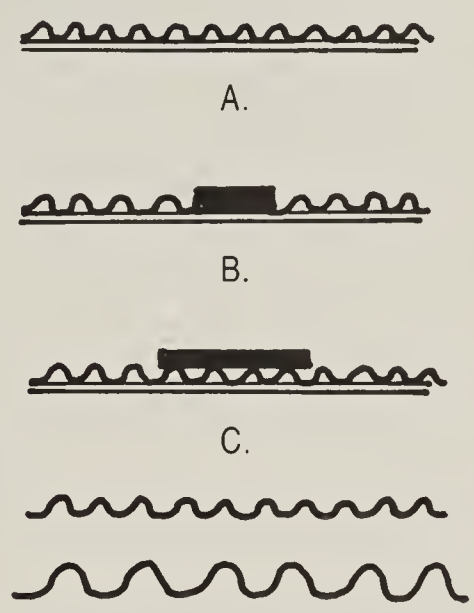
On the map of the Middle and Far East shown here, the canvas does not have a backing. The frame was cut to include a portion of the map. This technique gives added support to the map as a whole. Caution is necessary when handling maps made in this way, since they tend to be fragile. They should be placed between two sheets of cardboard when not in use. If the canvas is to be glued to a background surface, be sure to spread the glue thinly so that it will not fill up the areas between the threads and decrease the depth of the pattern.

Water can also be depicted by using crepe paper. Its use is

The master of a map of the Middle and Far East that has been mounted on embroidery canvas. The canvas represents water.

prevalent in England and Denmark. Crepe paper may be difficult to glue to the background of a master. Too much glue will flatten the ridged or crinkled surface and leave little impression on the plastic copy. Spread glue thinly over the background material with a spatula. Lightly pat the crepe paper into place on the glued surface. Glue in a spray bottle may be easier to use directly on the paper. Test such glue first before using it on the master to be sure that it can withstand the heat of the vacuum-forming process.

Corrugated cardboard in various degrees of coarseness (see A) is used on one-of-a-kind maps that will not be mass-produced. This material can be mounted in an east-west pattern. It is easily used by blind students who make their own maps. The countries or continents on these maps are often cut out of cardboard from packing boxes or from Styrofoam. The land area can be cut down into the corrugated cardboard (see B), or it can be mounted on top of the corrugated cardboard (see C) with glue. If the land areas are to be mounted temporarily, then use a nondrying putty for fastening the pieces in place. Styrofoam is sold in sheets of various thicknesses or in blocks and is available from display companies and art supply stores. It has a white, porous surface that can be cut with a knife or heated wire and can be painted if so desired.



Corrugated paper, with or without backing.

Bodies of water on a one-elevation embossed or microcapsule paper map can be depicted by a tiny dot texture. Dotted lines on these maps would then indicate rivers, as opposed to the solid line of a river on a vacuum-formed map. The solid lines on one-elevation maps usually stand for boundaries or roads (see "Symbols in Use Today," this chapter).

Water texture on any type of map should be extended to the outer limits of the map, as shown on the microcapsule map of a Swedish province shown here. A small edging of water texture around an area or country is confusing to readers and tends to suggest that the water is limited to that particular area.

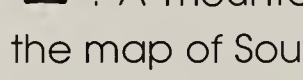
A microcapsule map of a province in Sweden, one of a series of maps of this area.

It is not always necessary to give water a texture. If the land on the map is raised and has an easily defined surface, the textured water may tend to clutter the display or be superfluous. This may also be the case if the land has a dominant texture of its own, as in the map shown here.

MOUNTAINS

Symbols for mountains are not yet standardized. Map procedures in each country seem to pile up layers of cardboard, sandpaper, and papier-mâché to achieve some sort of elevated plane. Some countries have tried to use a symbol similar to or . These symbols may be confusing, since the first symbol stands for men's toilet and the second stands for traffic lights in the collection of symbols in the Nottingham Map Making Kit (see "Symbols in Use Today," this chapter). The best suggestion is to follow your own thinking and touch.

When making a master in the buildup technique for mass-producing plastic copies, do not make the level of elevation so high that the display could be squashed when it is bound into a book. This consideration does not apply to unbound relief maps.

Mountains on microcapsule paper maps can be made by using a small triangle . A mountain range would look like this  , as in the map of South America shown on the next page. Leave 1/8 in. (3 mm) or more around each mountain symbol when placing it in a textured area on a microcapsule paper map, as in the coastal map also shown on the next page. This will help the reader to recognize these symbols readily.

The zigzag type of line does not seem to work with other lines on a microcapsule map. Readers can confuse the zigzag line with other solid lines, such as those used as borders or as the outline of the country. Using the mountain symbol eliminates this problem.

A microcapsule paper map in which mountains and rivers are represented.

Key

rivers

mountains

A microcapsule coastal map for beginning readers.

Key

land

mountains

1. peninsula
2. archipelago, islands, and skerries
3. island
4. promontory
5. bay, gulf (for larger body of water)
6. inlet, cove, bay
7. strait, sound
8. river delta, mouth of river
9. fjord
10. lake
11. sea
12. isthmus (neck of land).

CITIES

The size of a dot on a printed map often indicates the number of inhabitants living within a certain city or town. On relief maps, this technique is difficult to follow, although many attempts have been made to find suitable symbols that would give this information. The variations in the size and height of a dot are limited by the different production methods used in making relief maps and by the information, both physical (land elevation and water) and political (towns, cities, and local and national boundaries), that surrounds the dot.

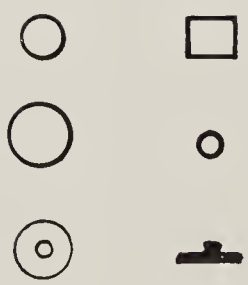
Many years ago, a combined effort of the Scandinavian countries produced a three-volume atlas (*Nordisk Atlas för Blinda*, 1966). The scale of the maps was 1:50 million—.04 in. (1 cm) equals 31 miles (50 km). The symbols used are as follows:

cities with over 1 million inhabitants.

cities with a population of over 10,000.

cities with a population of less than 2,000.

capital cities or places of government.



These fine distinctions seem to have been lost on readers. The main point was the location of the city. They could look up elsewhere how big or how small that city was. Over the years, the open square and the open circle have become a large open circle and a smaller open circle to indicate large and small cities or towns (population unstated). There is no definite dot size. Dots are scaled to suit each map as it is made.

Dots representing towns and cities can be made of hand-punched cardboard, leather, cork, fiberboard, or cotton glued on paper. For cities that require special attention, such as capitals, add a nail to the disk or use a metal snap fastener. Such fasteners are available in several different sizes.

NORTH

How does one indicate north on a map? It is necessary for the reader to know which way the map is oriented. Of all the methods in use today, not one suits everyone. Some of the methods are the following:

- A line of dots and dashes along the northern edge of the map, as used in the Nottingham Map Making Kit (see "Symbols in Use Today," this chapter),

  or a line of dots only. • • • • • • • • • •

- A single tactile line, such as a coarse length of string or a textured line,

  across the entire northern edge of the map. This system and the preceding one make it easier for the reader to locate north than the use of a small compass arrow.
- A large, simple arrow pointing north, with or without a braille letter *N* or the word *north* placed above or below it.
- The directional or tactile arrow (see "Arrows," Chapter 4) used along the edge of the map in a north-south direction. Using this arrow automatically forces the reader's finger to travel north, and creating it requires a special embossing instrument. This arrow should not be confused with the reading-direction arrow (see "Arrows," Chapter 4). It can be used on map pages that are included in a book, where its presence would indicate which way the map should be read—north would automatically be the edge farthest away from the reader.
- The title and scale of a map (or other information), written across the top line of the map, to indicate north automatically. This label eliminates all other indications of north, such as *N*, arrows, or lines. Such a system was suggested for further testing at the European Symposium on Tactual Town Maps for the Blind at Marburg, Germany, in 1985.
- A cut corner on the right- or left-hand side of the northern edge of the map. There is a risk that this practice may become confused with that of cutting off the top, left-hand corner of a page to indicate that the page is to be bound as a facing page. The reader should be forewarned if both systems are to be used together in a series of publications or in unrelated displays and books within a particular term or course.
- No symbol. North is always up. It is the opposite edge from the title, date, scale, and so on—provided that you always place this information along the bottom edge of the map.

- The title of the map, always placed in the upper left-hand corner. This placement indicates north, and no other symbol is needed.
- Three arrowhead notches cut into the lower edge of the map, pointing north (see Blasch & Brouwer, 1983).
- For building plans, the entrance to the building placed at the bottom of the plan. The direction north is indicated according to the placement of the building.

Whichever method or symbol you decide to use, be consistent in both the form of the symbol and its placement on the map, especially when making a collection of maps, an atlas, or maps in a step-by-step series. Be sure that your readers are informed about your choice of symbol for north on the map itself, in the key, or in the foreword or text if the map is included in a book.

TITLES

A title is definitely necessary. It lets readers know which continent, country, or town they have before them.

The reader must be able to locate quickly a particular map among other maps. Furthermore, the filing and cataloging of maps are usually done by title or title number.

The placement of titles on maps differs from country to country. Some producers prefer the title in the upper left-hand corner, immediately followed by the date, and the scale of the map placed along the bottom edge of the map page. Others reverse this layout by placing the scale and date in the upper left-hand corner and the title in the lower left-hand corner.

As just indicated, the placement of this information and the north symbol are intimately related. The old assumption that "this is north because the title is placed along the opposite edge of the map" indicates this relationship.

According to the most recent suggestion from the 1985 European Symposium on Tactual Town Maps for the Blind in Marburg, Germany, the map title, scale and so on should be written across the top line of town maps. This procedure is suggested because it would automatically indicate north and eliminate all other symbols for north.

The title, date, and scale of the map should appear at the

beginning of the key sheet, immediately above the list or register of symbols. If the key is an integral part of the map and is placed on the same sheet, it is not necessary to repeat this information because it is already printed along the edge of the map. If the key is on a separate sheet or sheets, the title, date, and scale of the map to which it belongs should be printed at the head of the key, before the symbol register.

Whatever placement of title on which you decide for your maps, try to be consistent in your production. Do not switch around the arrangement of title, date, and scale from map to map.

DATE

The informative value of a map is increased if the date—the year of production or the year the survey of the area was made—is printed on the map. Floor plans of buildings may be altered with time. Cities grow, streets change names, subway lines are extended, and new highways are constructed. Countries may change their boundaries, their names, or the names of their cities. Maps are often outdated and should be updated and improved.

The date should be placed as close as possible to the title of the map. Some producers place the title, the date, and the scale of the map along the bottom edge of the map. If space is limited, it may be advantageous to place the date of production on the accompanying key immediately after the map title and above the symbol register.

Individual dates may not be necessary on maps that are bound into a book. In such a case, the production date should be stated on the first page of the book.

SCALE

Scale is the ratio between the size of something real and a representation of that thing, between a feature on the map and the same feature on the ground. The scale of a map or diagram should not be confused with its material size—the area of the material on which it is presented.

Scale is expressed in the form of a fraction. A scale of 1/5,000 or 1 to 5,000 means that 3/8 in. (1 cm) on the map is equal to 164 ft. (5,000 cm or 50 meters) on the ground.

People are often confused by the terms "large-scale map" and "small-scale map"; they interpret small-scale map to mean a map with more detail of a small area of ground than would appear on a large-scale map. Nothing could be farther from the truth! The scale of a large-scale map would be 1:5,000, compared to 1:5,000,000 for a small-scale map.

When considering the best scale to use, keep in mind that braille is a standard size and cannot be reduced. There must be room enough on the map to accommodate the braille symbols.

All symbols used on a map must be tactilely clear. Kiefner (1983b) suggested that scales of 1:1,800 be used for complicated areas of a town or country, 1:1,800-1:2,500 for uncomplicated sections of a town (street names to be written in braille), 1:3,000-1:5,000 for maps with a separate key (for orientation and overall maps), and 1:5,000-1:30,000 for general maps and overall maps.

The scale of a map should always be indicated on the map itself or on the key sheet. The title of the map, the date, and the scale are vital information that should be readily found by the blind reader. It is desirable to indicate the map's scale both by a fraction and by a relief line showing a sequence of marks at regular intervals that can be used as a reference in making measurements on the map.

Scale can also be taken up on a tape recording or in a braille description of the map. Information could include, for example, that Bond Street, running east and west, is approximately 2 miles long. It is so-and-so many paces from the street crossing Main and State, east of the post office. Fifty miles south of Stanton is the village of Milton.

The reader should be informed of any distortion of scale on a map or diagram due to lack of space on the actual relief layout. It may be necessary to shorten buildings, roads, railways, rivers, and other elements.

Choice of Scale

The choice of a scale is determined primarily by the amount of information and the size of the symbols to be used on the map. The mental capacities of the reader, his or her ability to read braille, familiarity with relief maps, and independent travel

experience also play a decisive part in the choice of the scale of the map.

A larger scale is often necessary for the following reasons:

- The readers are young and unfamiliar with relief maps. They often need more space around symbols to locate and recognize them than do their more experienced classmates.
- The quantity of information to be presented requires a larger area to avoid crowding.
- Relief-print letters for nonbraille readers take more room on a map than do braille characters.

Enlarged or Diminished Scale

Use a grid system to enlarge the scale of a map manually. Draw a network of horizontal and vertical lines forming 1 in. (2.5 cm) squares on top of the printed map that is to be enlarged. Make another network of horizontal and vertical lines on a blank piece of paper or cardboard, this time increasing the size of the squares from 1 in. (2.5 cm) to 2 in. (5 cm) or to whichever ratio you may prefer. Draw the map on this enlarged grid system following the original map point for point by placing the same information at the same intersecting lines.

To decrease the size of a map manually, follow the procedure for enlarging it. However, decrease the size of the squares instead of increasing them. Enlarging or decreasing maps can also be done by using a pantograph, a simple tracing instrument consisting of four pivoting arms, with which drawings can be copied to any scale (see "Enlargements and Reductions," Chapter 7), an office copying machine that copies in varying sizes by photographic enlargement, or an overhead or a slide projector to project an image onto some type of background material that has been attached to the wall. Decreasing the size of a map can be done by reversing the lens of a slide projector.

SIZE

It is difficult to state a definite size for maps because so many variables are involved. Many of the same factors that govern the choice of scale govern the choice of the size. Size depends on the amount and type of information to be

described, the capacities of the readers, and the production methods to be used.

Size is a controversial topic. Some people say that fingers are not as good as eyes in discerning small objects; therefore, maps should be large so that readers can understand what they feel. Others say that maps should be small so that the readers' fingers can take in as much as possible at one time. This controversy is discussed further in Chapter 3.

The size of maps should in general be such that the user can cover a significant portion of a map with one hand and orient himself or herself with the other hand (see Wiedel & Groves, 1969).

Mobility teachers generally agree that a mobility map should not be larger than the span of two hands placed together with the fingers outstretched. The hands provide an ideal frame of reference, and this allows the components of the map display to be more easily related to each other (James & Armstrong, 1976).

The minimum size of a map is governed by the following:

- The 1/4 in. (6 mm) rule of space needed between lines.
- The 1/8 in. (3 mm) distance needed between point symbols.
- The 1/2 in. (13 mm) minimum size for textured areas.
- The accommodation of standard-size braille for labeling the various components in the map.

Maps that are too large are difficult to handle. It may be advisable to divide them up in booklet form, which would include a simplified overall map and an extensive key or register. As Dixon (1984, p. 33) noted: "A bigger map is not necessarily a better or more understandable map. Large displays take longer to explore, can be very inconvenient to transport, and may not provide a clear idea about the relationship of one part of the map to another, simply because of the distances involved between points." Some mobility maps should be made in a small size so that the reader can carry them with him or her into the field.

LABELS

Labels can consist of short descriptions, single words or names, letters, abbreviations, or numbers. They can be embossed

directly on a map or on paper or foil that is then cut and glued to fit into a particular area of the map. If the space for labels on a map is at a minimum, you may wish to insert a description in the key, such as the following: "Below, or south of, Littletown is the Stone River; Belmont is a small town west of Jason City."

Suggestions for Labels

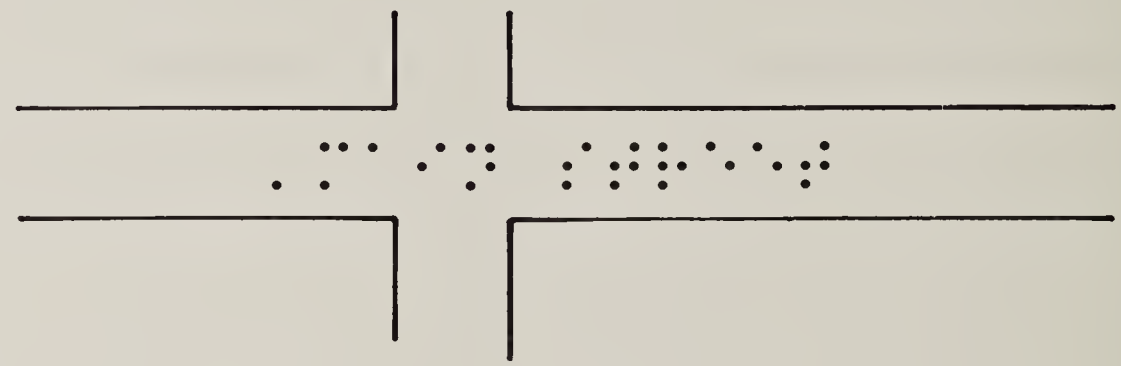
The following guidelines for labels are the same whether the labels appear in a picture display or on a map. The comments in Chapter 4 are as pertinent here as they are for pictures.

- Labels must be placed so that they do not distract readers from the symbols or areas that they identify.
- Standard braille is the best text size on most tangible graphic displays. However, there are exceptions. In cases of cramped quarters and maximum-size maps, the small braille slate—English microbraille from the Royal National Institute for the Blind (RNIB) (see "Sources of Materials and Equipment," Appendix 3 for address)—has been used. The braille is acceptable for high school and university students, although it may not be well received by some adult map readers.
- If a braille text is necessary, keep it short. A verbal explanation of the map is often more easily understood than a printed one. A verbal explanation can be made in person or through a tape cassette. For nonbraille readers, such a tape would be the key to the map.
- Single letters or a combination of letters to indicate the name of a country, city, river, and the like are more easily remembered than are impersonal numbers that must be constantly referred to in the key. The letters should have a connection with the actual name of the area (for example, KS for Kings Street, HB for Hudson Bay, and P for Paris). Some people make a sport of trying to figure out the name of the place indicated from the letter combination on the map. This is true for both braille and inkprint letters.
- Adding labels may tend to overcrowd the display. If such is the case, increase the scale of the map or put the braille or relief-print labels on an overlay to the map.

  Should the direction of the label on the map be north-south or east-west? This would depend on the use of the display. Is the map to be bound into a book, clipped

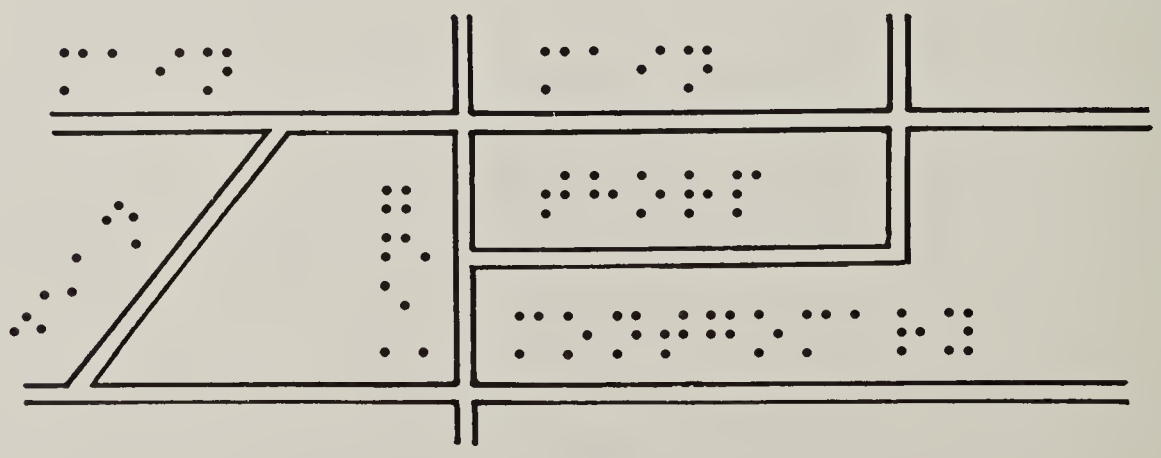
together in a series of maps, accompanied by overlays and underlays, or just be a single map?

- Generally speaking, braille should be printed parallel to the top edge of the map sheet. The direction of the braille indicates to the reader the way the map should be read. Most often the upper edge of the map indicates north. General reference maps, a category to which the bulk of geographical maps belong, are labeled this way, as are the majority of bound maps.
- Large-scale mobility maps may use the block system for streets (see A; see also "Mobility Maps," this chapter) or single or double lines. Street names can be printed on the wide line (block system), between the parallel lines, above or below the lines, or on an overlay or underlay.



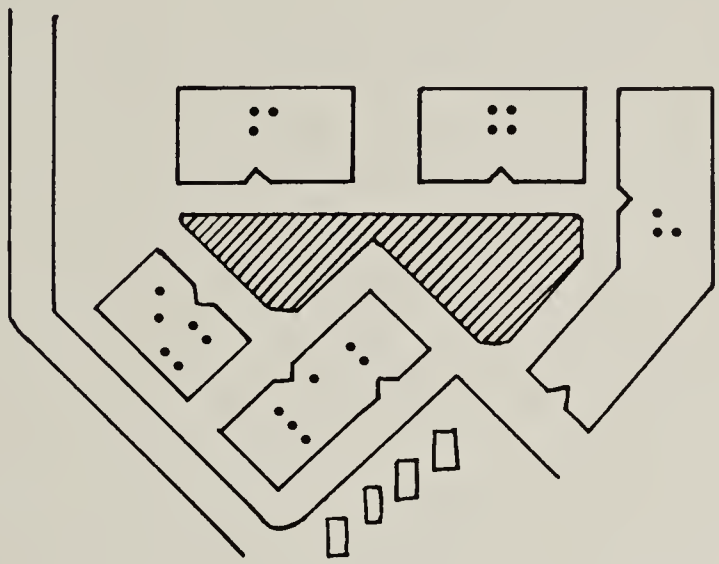
A.

- Names should be placed as close as possible to the object they identify. Shorten the name, abbreviation, or number if it is too long for the given space on the map. Explain this change in the map key. James and Armstrong (1976) suggested that labels be placed above roads running east and west and to the left of roads running north and south (see B).



B.

- Be consistent in whichever labeling system you choose. Try to use the same system throughout the map or series of related maps.
- Labeling buildings or streets may be difficult within a limited space. Fit the label into the direction of the building or street (see C).



C.

- A map may not always be read while the reader is sitting at a table. A blind map reader who is standing up will often read a map by placing it against his or her stomach, turning the map this way and that to get the feel of the area presented. Consequently, those braille labels that are not parallel with the top edge will be read in their proper direction in spite of their placement on the map. However, this system of scanning is not to be counted on when making a map.

Label Making

- To conserve space, the braille symbol for a capital letter is often eliminated on relief maps.
- If you are brailling directly on aluminum foil, be careful not to press down areas already embossed into the foil. This can easily be done with the two panels of the brailling slate. It may be advisable to braille the foil first, if possible (see "Braille," Chapter 4).
- When adding labels to a map, do not cut paper, tape, or foil labels too close to the braille cells. Keep the edges of the label squared.

- Various plastic tapes can be imprinted with braille characters or with relief letters and numbers of the inkprint type (see "ABC and 1, 2, 3," Chapter 4). These labels are practical on a one-of-a-kind map. However, they should not be used on a map that will be mass-produced by the vacuum-forming process unless the tape is resistant to heat of 392°-572° F (200°-300° C).
- Instant dry-transfer letters or numbers in both braille and print can be added to microcapsule paper displays (see "Braille," Chapter 4). However, use the relief-print letters and numbers sparingly. Blind readers easily confuse them with other symbols on a map. These letters are usually used to accommodate travelers with low vision or to make a map legible to sighted people. For such readers, the letters can be typed or printed on a map that has already been swelled. Do not add instant dry-transfer letters or braille directly to a swelled microcapsule paper map that will be reheated or swelled once more. These symbols are printed on a thin film that will burn when subjected to intense heat. Large-print letters for nonbraille-reading blind travelers can be used on microcapsule paper maps that are made for such use (see"Tactile Maps for Nonbraille Readers," this chapter).
- On labels on vacuum-formed maps for nonbraille readers, the use of inkprint letters and numbers necessitates a larger scale of map to accommodate the enlarged relief characters (see "ABC and 1, 2, 3," Chapter 4).
- For suggestions regarding labels and text on maps used by low vision readers, see Chapter 9.
- New labels can be added to paper or plastic maps that have already been produced. Brailled tapes or embossed paper or foil labels can be fastened to the original map or an ordinary slate and stylus can be used to emboss directly on the map, provided the area for the added information is within the scope of the two leaves or panels of the slate.
- To add information to microcapsule maps, use a lead pencil or a black felt-tipped pen directly on the relief map. Place the map in an infrared heater-fuser. The new information will swell to the level of the original display. A map can be reheated two or three times before it shows signs of being overheated.

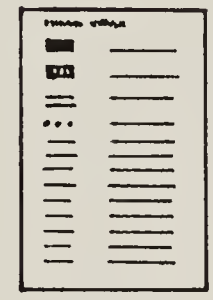
KEY OR LEGEND

A key or legend unlocks the information contained on a map. It is a list of all the symbols: lines, points, and areal patterns, combinations of letters and numbers used on the map, and an explanation of each one of the items listed.

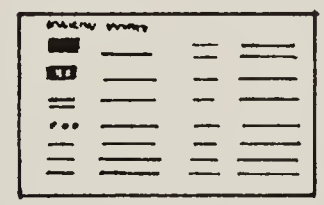
Format

The standard format for a key sheet is as follows:

- The title of the material to which the key belongs appears first.
- The symbols are placed in a column on the left-hand side of the key sheet. Braille descriptions are placed opposite each symbol in a column on the right-hand side of the key sheet. Do not place these columns too far apart. Fingers should be able to move easily from a symbol to its description.
- Most keys are made with one symbol column and one description column (see A). This format is easier to read than a key with two double columns (see B).
- The line, point, and areal symbols are usually placed first in a key. Their size should be exactly the same scale as those used on the map. For readability, the lines should be no less than 1/2 in. (1.3 cm) long and preferably longer; a textured area should be placed in a box no smaller than 1/2 in. by 1/2 in. (1.3 cm by 1.3 cm) and preferably larger.
- If microbraille characters are used on the map, use the same letters in the left-hand key column. The description of the symbols should be made in standard braille in the right-hand column.
- Letters should be listed in alphabetical order and numbers in numerical order. One or two letters used to indicate the name of a country, city, or river are easier to remember than numbers used for the same object (see "Labels," this chapter).



A.



B.

Placement

The key is usually placed on a separate sheet that may be attached to the map. (For further suggestions, see "Key or Legend," Chapter 4.) The reasons for this placement are as follows:

- A key made on the map itself could be mistaken for a part of the map.
- The reader may want to remove the key once he or she is familiar with it, especially when working with mobility maps.
- A key could also be made on the overlay or the underlay sheet to the map. This placement is used when these sheets contain additional information to the basic layout of the map.
- A separate key is recommended if there is a chance that the map will be used by people in other countries at some future time. The key could be translated into other languages and fastened to the display, as shown under "Format" in Chapter 3.

Additional Information

Some maps are made with a system of numbers and letters along the outer frame of the map or numbered squares in the map or in sectors indicated on the map. These systems are used to make it easier for the reader to locate a particular area. The reference letters and numbers should be included after each country, city, building, street, and so forth listed in the key (see "Index Grids," below, for more about these reference systems).

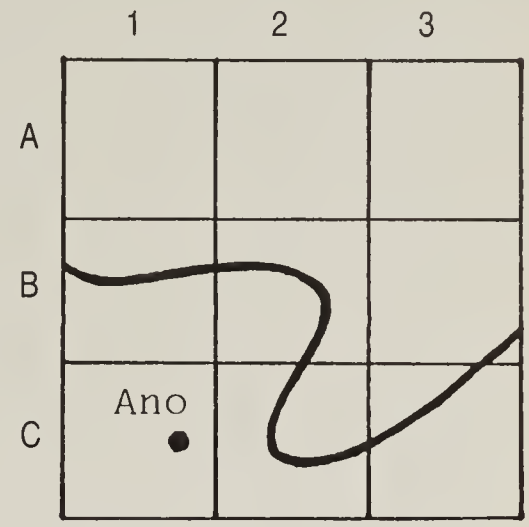
Finally, a map's key may also include these items:

- the street number of a house or building that appears on the map,
- information regarding numbers on a particular street (for example, "Number 1 begins at the south end of Green Street"),
- general information on street numbers (for instance, "All even numbers are on the right-hand side of the street, and all odd numbers are on the left-hand side").

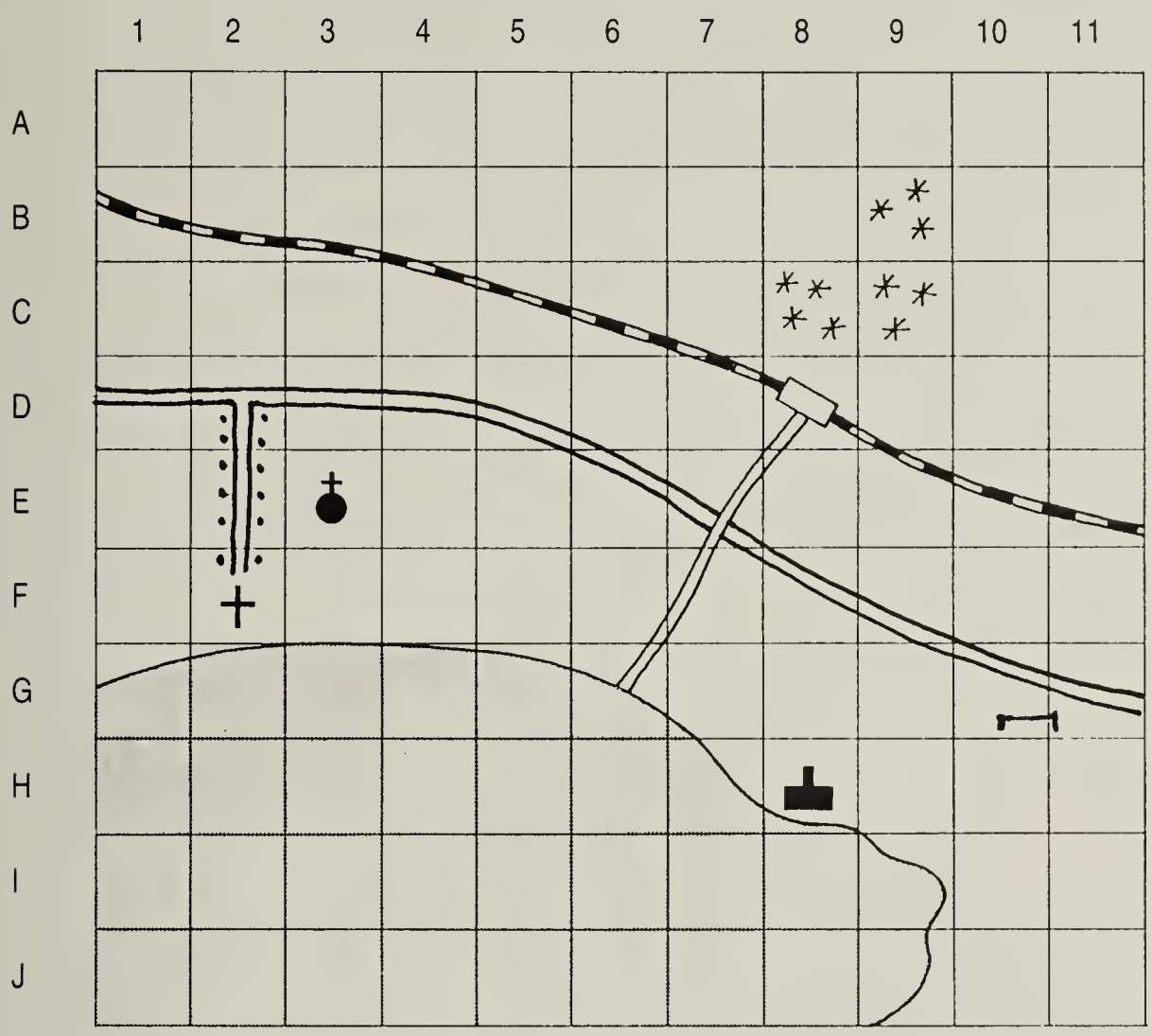
INDEX GRIDS

A grid consists of a network of evenly spaced horizontal and vertical lines that can be placed over a map or building layout to help the reader locate a particular area. In the vertical margin the grid is lettered in alphabetical order; in the adjacent horizontal margin the grid is in numerical order. In the grid

reference system shown in example A here, Ano is in C1, as it would appear in an alphabetical index or a map key. C1 indicates the approximate location of the city on the map.

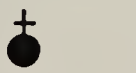


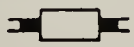
A.



B.

The map shown here (see B), made for sighted students, is a good example of the use of the grid system. This type of index grid on a relief map is often made as an overlay sheet (see "Overlays and Underlays," this chapter). The basic map can usually be felt through a thin plastic overlay. If the overlay is thick, it may be necessary to use one hand on the map and one on the grid to locate a particular point. Reference to these intersecting lines may appear in the map key as follows:


Minister's house E3


Railway station D8

Church F2

Factory H8

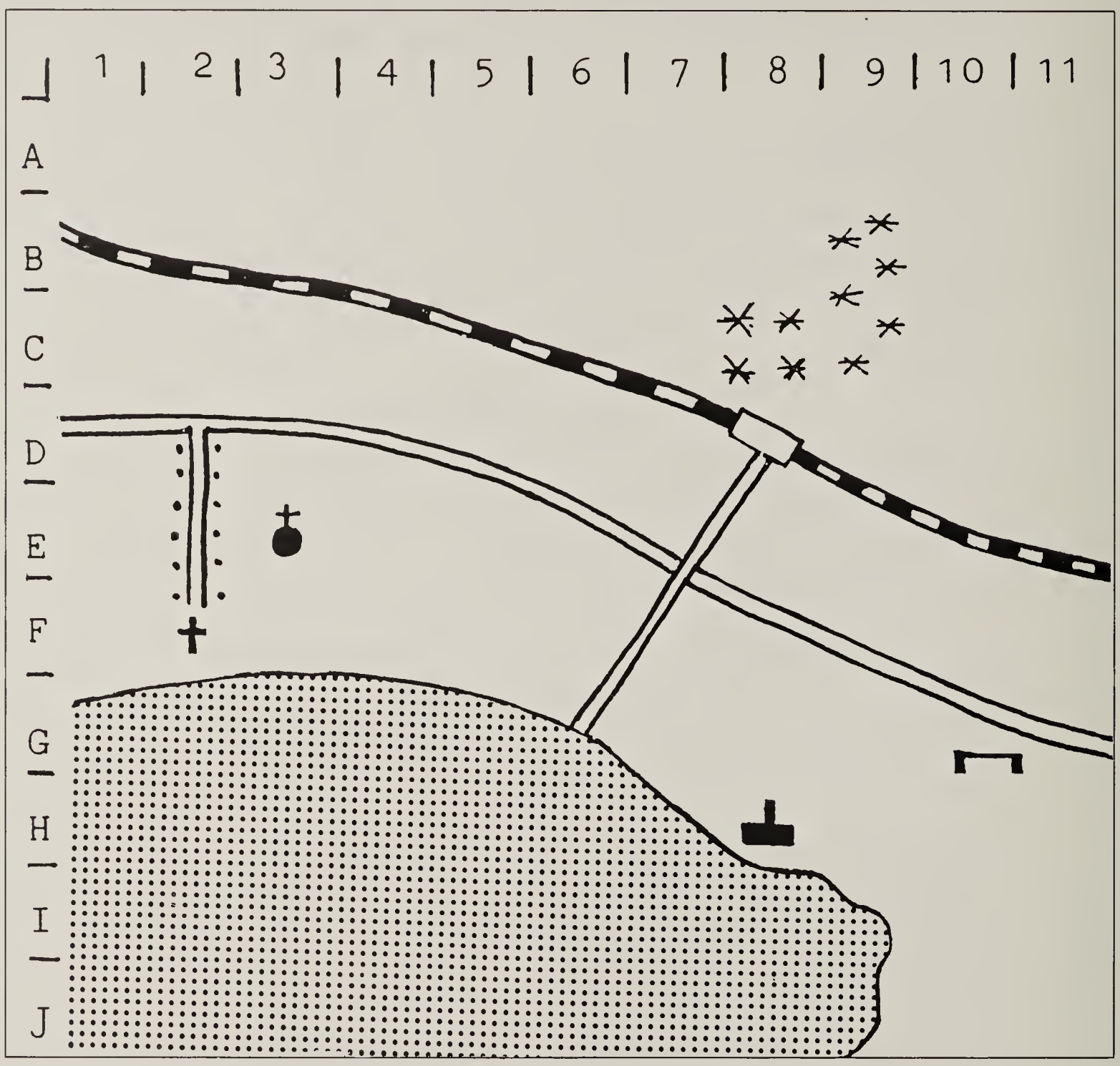
Woods B9, C8-9

Road D1-G11

Farm G10

Tree-lined road D2-F2

A grid can also be indicated on a map by a system of lines, letters, and numbers along the outer edges of the map itself (see C). The remaining two sides of the map can also be grid marked if desired.

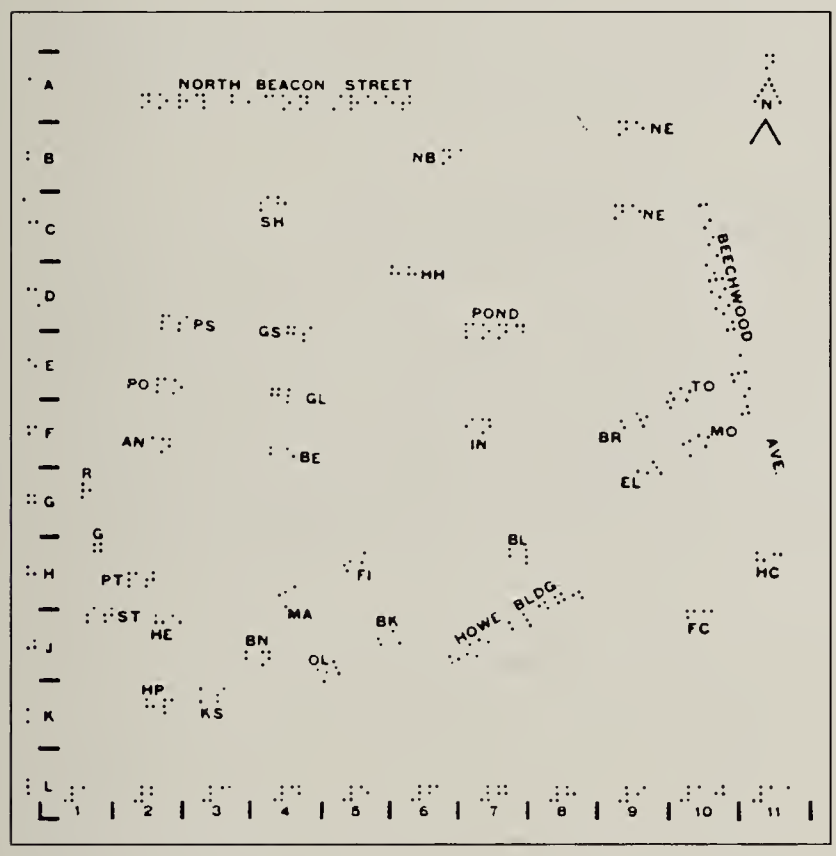


C.

The index grid on a relief map can be marked with braille letters and numbers or with both braille and inkprint letters and numbers. The following are some suggestions:

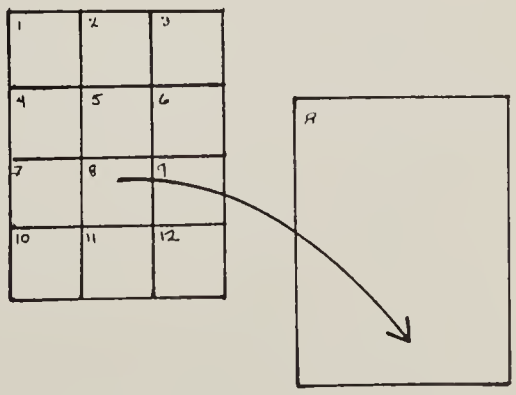
- A grid on a relief map should not interfere with the reader's ability to understand the map itself. The grid is only a guide; it is not part of the basic map. Therefore, the grid lines should not be dominant.

- A master for an index grid, such as an extra sheet, could be made on a sewing machine with a fine needle (see "Embossed Paper Displays," Chapter 2), with a fine spur wheel, or with a preglued, thin thread (see "Paper Buildup Displays Using Additional Materials," Chapter 2).
- If the grid is made directly on a thin plastic sheet, such as that used on a raised-line drawing board, any of the embossing techniques will work.
- Grid markings along the edges of the map reduce the reader's confusion if the grid is to appear on the same sheet as the map.



The overlay shown here (*left*) was made for a campus map (*right*) of the Perkins School for the Blind (see Bentzen, 1972). The overlay was embossed in transparent acetate.

A grid mounted directly onto the master of an orientation or general reference map becomes an integral part of the plastic copy of the map. Its purpose is to divide the overall map into numbered sections. Each section corresponds to a separate map, which is an enlargement of that particular section. For the illustration shown here, the braille numbers or letters in the upper left-hand corners of the grid sections correspond to a similar figure in the upper left-hand corner of the enlargement.



This system of an overall map, key, and enlargements is often put into book form. The book as a whole is seldom used in the field, although certain sheets may be useful for the traveler at some time.

To add a grid to a plastic copy of a map that has already been made, do any of the following:

- Use thin tape.
- Use an embossing wheel on the back side of the map, if the relief areas are low.
- Use a sewing machine to make the lines, with or without thread.
- Use liquid plastic made for painting on glass. It comes in a tube with a thin nozzle and can be applied in a long line.
- Use a lacquer pen. This pen looks like an ordinary felt-tipped pen but is filled with lacquer instead of ink.
- Mount the plastic copy on a firm background and stretch rubber bands or string across the map at desired intervals.

OVERLAYS AND UNDERLAYS

An overlay is a sheet that is placed over the relief map; an underlay is a sheet that is placed under the map. The purpose of these sheets is to add information to the original map. The sheets should be carefully aligned so that the information on them falls directly over or under the related information on the original map.

One or Several Overlays or Underlays?

As in a step-by-step series of maps, when using overlays or underlays, the basic map is simple and devoid of all unnecessary details. Even text or labels may not be necessary. Thus, the number of overlays and underlays depends on the amount of information that is needed for a particular group of readers. Some sheets that may be useful are:

- Names, abbreviations, numbers—in braille or relief-print text—for streets, areas, buildings, rivers, and so forth.
- Index grids that can help the reader locate a particular area.
- The location of walking areas; train, bus, or subway routes; train stations; bus stops; taxi stands; and so on.
- The location of paved areas, buildings, landmarks, dangerous areas, parking lots, main entrances to buildings, public telephones, mail boxes, fences, and so on.

- The location of crosswalks where the traffic lights are equipped with bleeper tones to indicate when pedestrians can cross.

Overlays and underlays are particularly useful for showing the relationship among such elements as different floors in a building, the different levels of a subway system, and the different layers of an archeological excavation.

Reading Overlays

As James and Armstrong (1976, p. 16) noted:

> A tactual map and one overlay can be read simultaneously with both hands; one hand on the map and the other on the overlay. In order to do this successfully, care must be taken that the labelling or other information on the overlay sheet coincides with the corresponding feature on the map. A series of overlays carrying different types of information could easily be prepared for the same map and any two used simultaneously.
>
> Unlike the overlay, an underlay sheet may be attached directly to the tactual map by using Twinstik. Both hands can be used to relate information on the topside and underside maps.... If braille is placed on the underlay, care must be taken to ensure that the map-reader does not read the underlay as the topside of the map since this has the effect of reversing information on the map itself.

In the United States, it has been found that underlays are easier to use than overlays because the overlay comes down over the hand and disturbs the person's reading. As Dixon (1984, p. 34) explained:

> A point or area on the overlay or underlay must be compared with the same point on the basic map. An overlay can be a bit awkward to use because the hand which is locating the point on the basic map can get in the way and make proper positioning of the overlay very difficult. Using an underlay permits the two parts of the map to be compared by placing one hand on top of and one hand underneath both parts. If the map material is somewhat flexible, the finger on the point that has been located on one map surface can be felt through both maps with the other hand.

Further Tips

Overlays and underlays are used mainly with plastic maps that are mass-produced. These separate sheets can be made of transparent or opaque plastic. The transparent plastic may be helpful for low vision readers if color has been added to the original map. For example, the transparent sheet could have areas of varying relief textures that would fall over the colored areas of the original map (see Chapter 9).

The thickness of the plastic overlay depends on its use. If it is necessary to feel the streets, symbols, and relief forms through the overlay, then choose a thin plastic—.004 in. (.10 mm).

To make an overlay, or an underlay, use the same process as for one-of-a-kind maps or for making a master that will be used in the vacuum-forming process (see Chapter 2). If the overlay or underlay is not attached to the original map, be sure that the dimensions of these sheets and the map are the same so that the reader can place the sheet properly and the information will always fall at the same points. This is absolutely necessary when making grid sheets.

Braille paper as an overlay can be embossed with spur wheels, a freehand drawing stylus, the sewing-machine technique (good for grids), a braillewriter, a slate and stylus, and so on (see Chapter 2). This paper can also be used as a master to produce plastic copies if desired.

MOBILITY MAPS

Mobility, the ability to travel independently, is an instrumental ability. It is instrumental because anything else that visually impaired people may want to do is likely to depend heavily on their adeptness in traveling alone to get where they need to go to do what they want to do. And for this they need maps!

Mobility maps, often called safe walking maps, contain information on a limited local area. They are usually made on a large scale because of the nature of the information they contain and the necessity of labeling individual items.

As the mapmaker, you must decide on the type and amount of information to be shown on the map, identify useful nonvisual clues, and choose the production technique to be used. Before you make a map:

- Carefully question your reader about the task he or she

expects to perform with the particular map. The reader's needs may not be those you had anticipated.

- Also determine the reader's experience in traveling independently and his or her ability to read relief maps. These will be decisive factors in forming the character of the map.
- Contact community offices, libraries, tourist associations, the chamber of commerce, schools, architects' offices, and police stations within the desired area to find out if a printed map of the city, schools, public buildings, parks, and shopping areas is available. Such a map can be the basis for a relief map but should be evaluated carefully, since the information presented is meant for people with sight.

No audio aids—no fountains, waterfalls, ticking crosswalk signals, or chiming clock towers on churches, schools, or city buildings—are indicated on a printed map. No mention is made of surfaces or materials such as gravel walks, areas with paving stones, or street crossings without curbstones that are designed for easy access for wheelchairs, baby carriages, and bicycles but are difficult for blind people to detect with their canes. Signs and stands on the sidewalks, areas used to park bicycles and unload trucks, free-standing mailboxes, and fire hydrants are other hazards that will not be encountered on a printed map. And trees, potted plants, scaffolding, flagpoles, entrance steps to stores, and street-repair barricades are definitely not mentioned. Yet each of these items can be a danger point or a landmark for the blind traveler.

Therefore, it is advantageous for you to visit the area before creating a relief map. You can see the incline of the streets, the direction of stairs, the intensity and direction of traffic patterns, and the location of pedestrian overpasses and underpasses; experience the open areas as opposed to built-up areas along the blind traveler's probable route; and discover confusing areas that the printed map does not indicate.

The following list of problem areas encountered by blind travelers, compiled by Preiser (1983), may be helpful when you look over prospective areas for making relief maps. These problems are found outside buildings:

- Changes in terrain, from flat surfaces to steep inclines or declines, from a gravel to an asphalt surface, and the like

- Hanging or protruding objects
- Curved paths that deviate from the general layout of perpendicular streets and walkways
- Obstacles
- Landmarks
- Vast open areas
- Parking lots
- Weather-related problems, such as slippery areas
- Stairs.

According to Preiser, the following problem areas are found inside buildings:

- Entrances
- Doors
- Lack of braille markings or other indicators of direction
- Curved diagonal paths
- Hanging or protruding objects
- Excessive noise preventing the blind person from hearing his or her own footsteps on the walking surface
- Changes in level
- Stairs.

These clues or elements in the environment are among those that can be added to assist the map reader:

- Tactile clues
- Auditory information
- Information relating to the sense of smell
- Information about temperature
- Barriers such as walls, railings, rails, and windows
- Special hazards present in the area, for example, road or building construction
- Crosswalk signals that are automatic or constant or can be activated by pedestrians.

Suggestions

- The amount of necessary or desirable information may be too much for one map. Therefore, a series of maps or layouts made from one basic map may be necessary.
- Consider the permanence of certain objects on the projected map. A bus route could be changed tomorrow. A

separate overlay or map would save the time and trouble of remaking the master for a vacuum-formed plastic copy if the route were changed.

- Microcapsule paper maps of shopping centers and business areas of towns or cities should be kept up to date. Names often change, new buildings appear, and traffic patterns and transportation systems are rerouted. As soon as changes occur, you should make an altered map of the area and distribute it to the organizations and individuals concerned.
- Determine where the map will be used—in the field, in the classroom, or at home? This question influences your choice of size, whether the map should be made to be folded, and whether the map needs to be resistant to weather conditions.
- Are color and inkprint text on the map worth the additional effort and cost? These additions would increase the number of potential users to include persons with reduced sight, which in itself is an economical advantage.
- A verbal or written description of the map area may eliminate the need for overlays, underlays, or a series of maps. The description could contain auditory, physical, and tactile landmarks, danger areas, an explanation of the local transportation systems, and other useful information.

Remember that visually impaired readers do not have your ability to understand a map at a glance. A sweep of their hands over a tactile map reveals nothing but bumps and lines until they study the relief material bit by bit. To gain a mental picture of the entire layout of a city or town, the reader should be able to study several maps of the area. The following discussion contains suggestions for three types of maps.

Map 1

This map should be simple, small scale, and undetailed, containing (1) the geographic features of the area, including canals, rivers, lakes, shore lines, and islands, (2) the location of communities or districts (when space or simplification does not permit the use of boundary lines, a name or keyed symbol is often sufficient), and (3) two or three important landmarks as orientation points (repeated throughout any accompanying

maps whenever possible). This information will give the reader a comprehensive idea of the size and location of these areas and their relationship to one another.

The map should be made with an index grid or system of lines, letters, and numbers along its outer edges. This grid facilitates the location of specific information, as well as the areas covered by any accompanying special section maps.

Map 2

This map should show a large-scale section of those city areas that are most frequently visited or of importance to the blind traveler. Some items to be included are streets, street names, transportation systems (railway, bus, and streetcar lines and their stations and stops), subway entrances, significant buildings, and any landmarks from map 1. This type of map can have a simple or a complex layout, depending on the ability of your readers (see "Map Theory and Practice," this chapter).

Map 3

This map should contain a magnified view of a small area of the city. It should be a large-scale map covering one or several city blocks with more detailed information. Stores, public buildings, cultural centers, stairs, building entrances, and telephone booths are some of the features that should be added (see "Map Theory and Practice," this chapter). Map 3 is often the map that travelers will want to carry with them. Remember this when choosing the size and type of material for this map.

Maps can be made on a raised-line drawing board, with movable parts, with tape on paper, embossed on paper or metal foil, with the paper-on-paper buildup technique, on microcapsule paper, by computer (see Chapter 2 for a discussion of these techniques and materials), or on a tape-recording machine. The production method will, in turn, direct the choice of symbols you use.

When making a map, it is helpful to do the following:

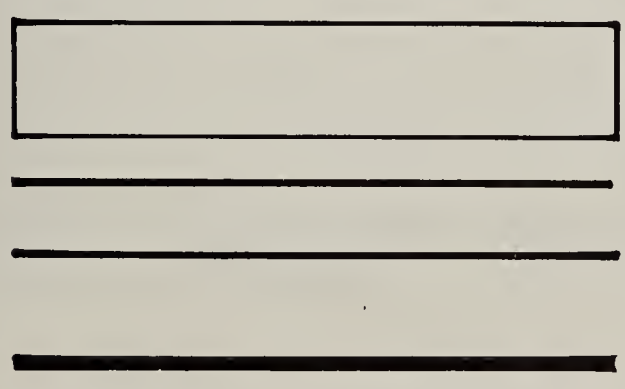
- Draw a map of the area or rework available maps and building layouts. Enlarge or reduce the printed material in a photocopier or office copying machine, by photography (reprocamera), by using a pantograph to redraw the area, or by using a projector or an enlarger that projects the

image onto paper or other background material on which a map can be drawn (see Chapter 7).

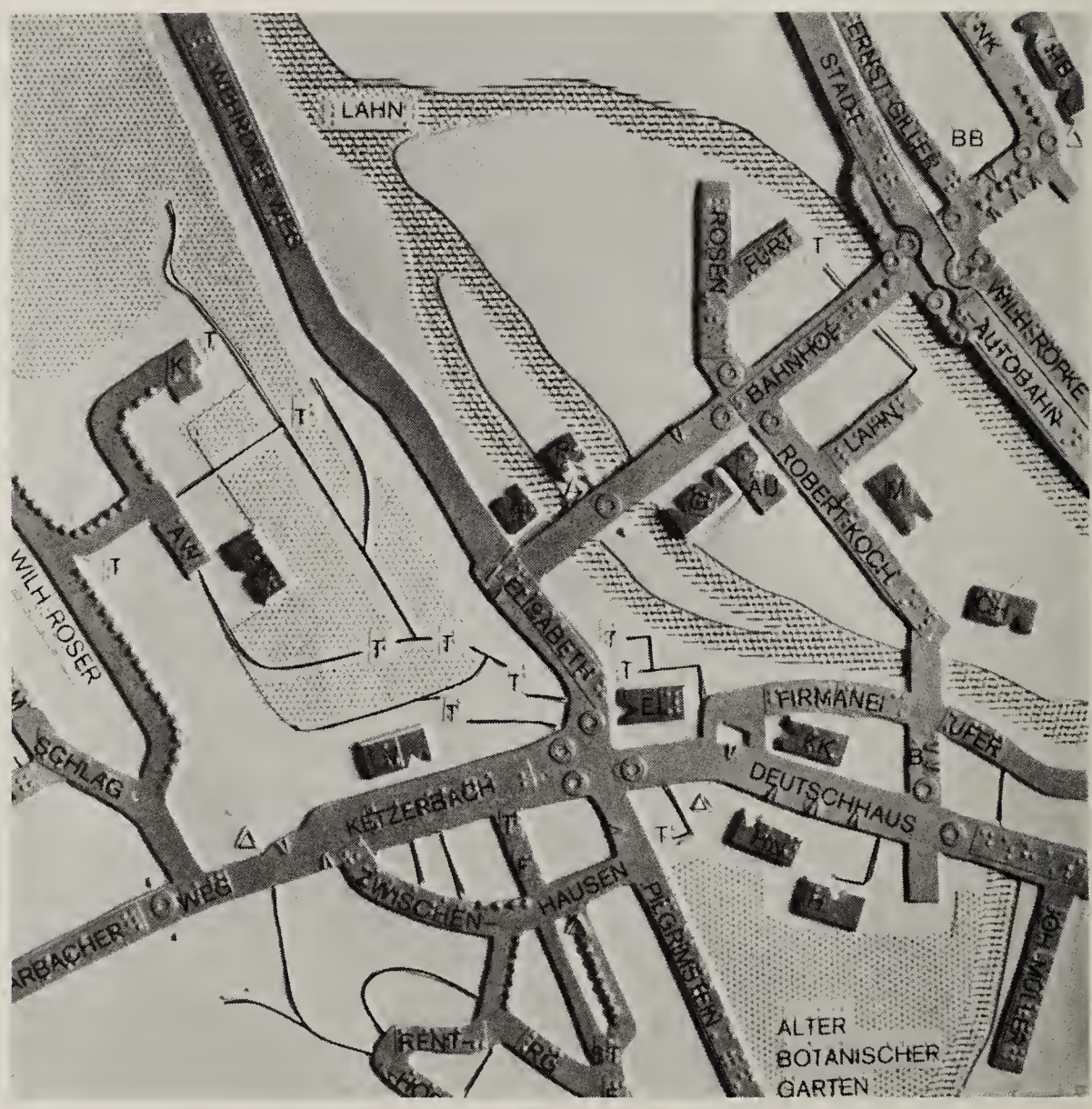
- Eliminate all details that are not essential to the blind map reader.
- Simplify those elements that are left on the map: building outlines, various sizes of streets, parks, parking lots, and playgrounds.
- If necessary, change the original map within reasonable limits by moving elements so that there is a minimum of 1/8 in. (3 mm) to the nearest symbol or by enlarging the elements so that they are clearly recognized for what they are. Blind travelers should be able to recognize the blocks of buildings and the streets surrounding them without difficulty. They should be able to travel on foot or by local transportation from point A to point B by recognizing the correct bus or subway stops and locating pedestrian crosswalks and building entrances.
- Keep distance relationships the same throughout the map. It is better to add another map sheet or foldout page or to enlarge the original map area than to reduce the size of city blocks because you think they are of little interest to the reader, who may want to explore the area at a later date and could be misled because of distortion in size. Remember, a numerical scale should always be printed on a map.

Streets and Landmarks

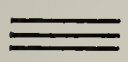
The block system (recommended at the European Symposium on Tactual Town Maps, Marburg, Germany, 1985), which consists of massive raised surfaces as opposed to the line system, as shown below, is more readily understood by the majority of readers of relief town maps. An example of this system can be seen in the map of Marburg, Germany, included on the next page.

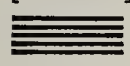


ABOVE: A town map of Nottingham, England. The streets are formed by pairs of parallel lines.



RIGHT: A town map of Marburg, Germany. The streets are constructed according to the block system. Inkprint text has been added for travelers with residual sight. This is a useful addition for the blind reader when help from a sighted person is needed.

It is possible to use the block system when a map is made with movable parts or tape as a one-of-a-kind buildup map or a buildup master for production of plastic copies. It is difficult to use the system on embossed paper maps because such an extensive, solid, textured area would weaken the paper beyond use as a master for mass-produced plastic copies. For streets on these maps, use two parallel lines with a space between them , as in the map of Nottingham, England, shown on the previous page, or three parallel lines together  .

The block system is difficult to use on microcapsule paper maps as well. When heated, large, solid, black areas on microcapsule paper tend to swell to such an extent that they may warp the paper. Use thinner solid lines (a maximum of 2 in. [5 cm]) or use many thin parallel lines drawn close together  . Instant dry-transfer patterns can also be used (see "Areal Symbols," this chapter).

When many streets and crossings are involved, the raised surface of the block system is easier for readers to follow. Additional information, such as street names, bus lines, and traffic lights, can also be located by readers and understood more readily on a solid surface than when between two parallel lines. Unfortunately, the technique of adding information to a raised road or area can be used only on a one-of-a-kind map or maps produced in a vacuum-forming machine.

The addition of both names and symbols to the raised street surface can mean too much information in one area and inhibit the use of bus lines, directional arrows to indicate the flow of traffic, and the like. In such a case, move street names above, below, or to the side of the street (see "Labels," this chapter). If you move one name, move them all. You must plan your map for readability according to the amount of information to be presented. It may be necessary to make several maps or to make an overlay for your map.

The widths of streets and roads adapted to braille should be .40 in. to .60 in. (10 mm to 15 mm) for main streets and .30 in. (8 mm) for side streets. Braille names or abbreviations can be printed on the edge of the street, leaving space to add other symbols directly on a "block" street, beside a single-line street, or in between the lines of a parallel-line street.

Streets with Pavement

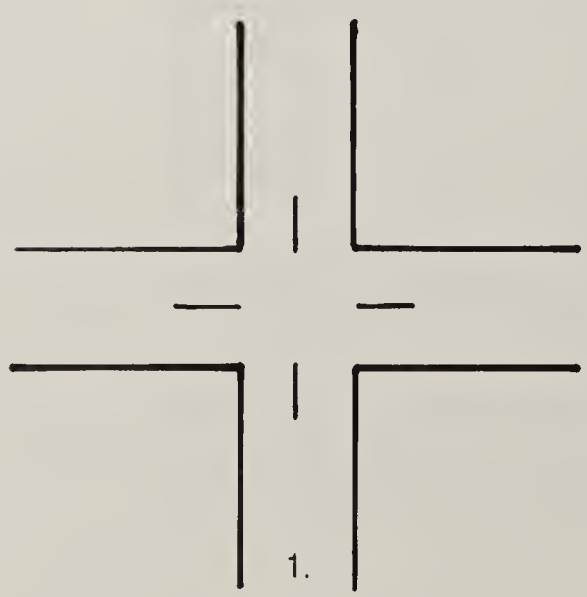
Pavement need only be represented at the request of the blind reader. In the case of nonexistent pavement or pavement that is dangerous to blind travelers, use the danger symbol from the Nottingham Map Making Kit (see "Symbols in Use Today," this chapter).

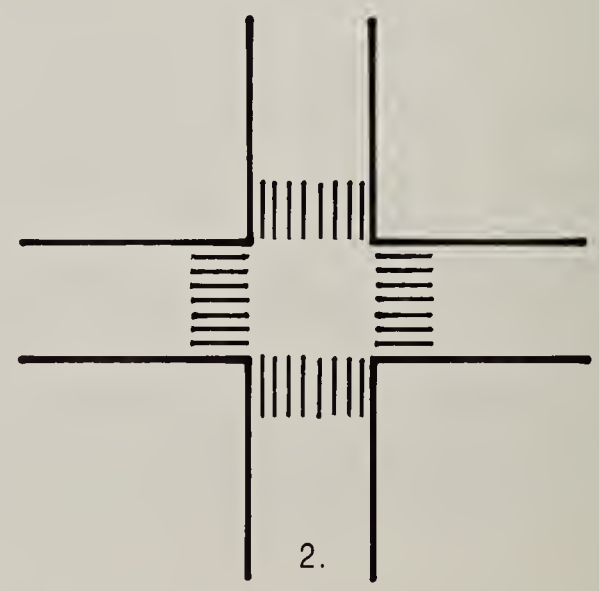
The surface of particular block roads or paths can be covered with a texture on special types of maps to indicate the special route of a particular blind person, to show the surface material of the road or walk or the direction or intensity of the traffic, or to signal a warning that the area is slippery when wet or that another dangerous condition exists. This can be done only when the adjoining areas are not similar to the chosen texture. Sandpaper, whose use seems logical here, is not advisable because it is most often used to indicate green areas on mobility maps.

Streets as Parallel Lines

In large-scale mobility maps, parallel lines indicating the streets may be more helpful to the reader than block-system streets because readers can visualize themselves walking along the line bordering the street. When they come to an intersection, they feel how the "sidewalk" comes to a corner and the crosswalk takes them across the street, as in intersection 1 shown here.

Crosswalks in many countries are marked on the streets with plastic paint. The stripes are slightly raised and can be felt underfoot. If this is common in your locality, the crosswalk may be indicated as in intersection 2 shown here. Be sure that this symbol cannot be mistaken for stairs.


1.


2.

Streets can sometimes be represented as single lines. When you produce general orientation maps at a scale of 1:5,000, the space may be limited. Wide streets on a map of this scale would make the area too crowded. (More information regarding streets is discussed under "Line Symbols," "Single Lines or Double Lines?" and "Labels," this chapter.)

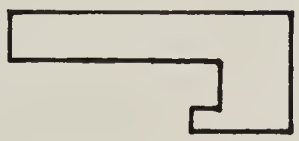
Landmarks

The word *landmark* can mean different things to different people. What appears to be a landmark to some may be considered a dangerous area to others. It is important to remember this when choosing useful landmarks for your map. Discuss the character and use of landmarks with your blind reader. The fact that the traveler may be using a cane, a dog guide, or some other mobility aid may also influence the choice of landmarks.

Recognition of Shapes

As Bentzen (1980, p. 306) noted, "One of the most difficult haptic tasks to be performed on a tactile map is shape recognition, whether the shape is an enclosed figure such as the outline of a building or the shape of an intersection." Unessential information can be substituted by an abstract or simplified version of the shape, as demonstrated here by the actual shape of a building and its simplified form.

Actual shape of building



Simplified form

Shapes seem easier to recognize in a small scale than in a larger scale. The larger scale takes longer to scan, and the reader may lose the concept of the object before he or she has completed the inspection.

SYMBOLS IN USE TODAY

The following symbols have been created primarily for orientation and mobility maps with several different elevations—plastic maps that are produced from a built-up master by using a

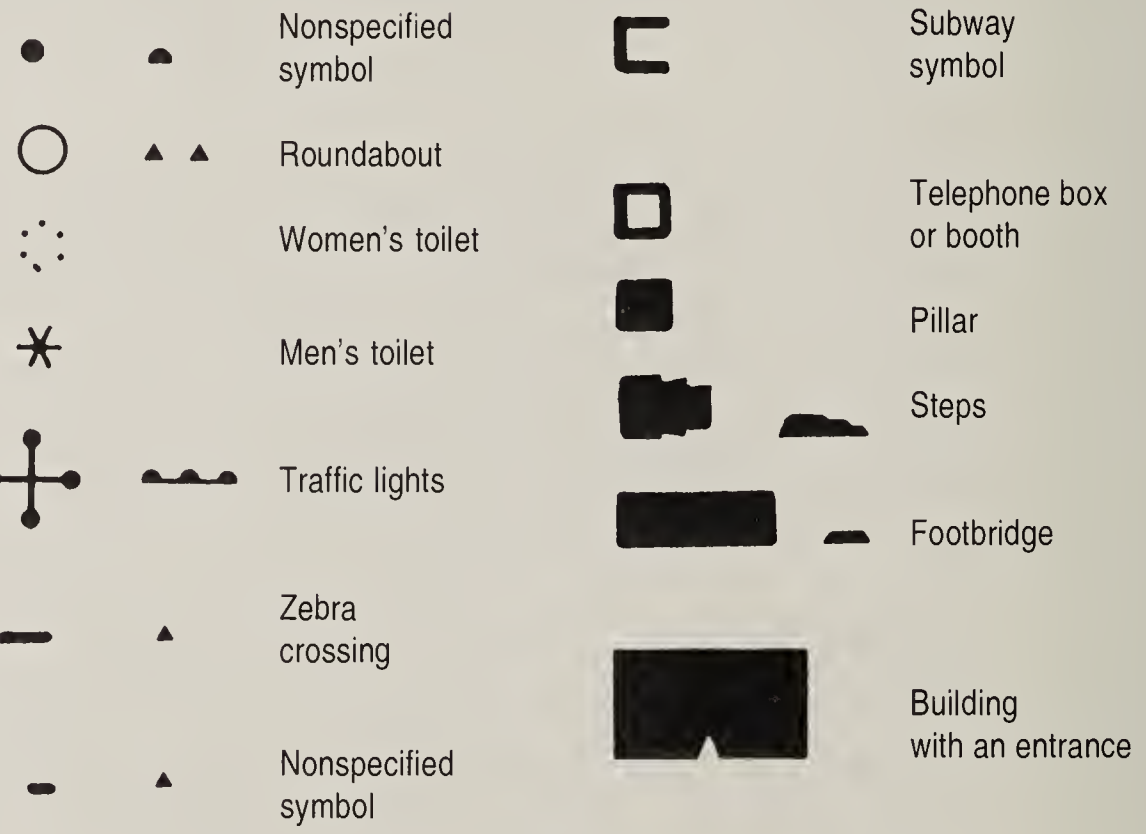
vacuum-forming machine. Their use on one-elevation maps and on microcapsule paper maps in particular is somewhat limited. Tunnels, stairs, bridges, and the like are definitely made for more than one elevation. Thus, other symbols must be made to fill this need. Substitutes can often be found on maps for sighted readers.

Symbols from the Nottingham Map Making Kit (and the Euro-Town-Kit)

Areal textures.

Linoleum | Sandpaper | Wire mesh | Plastic screen

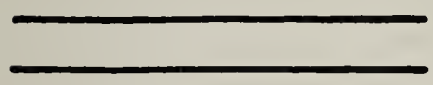
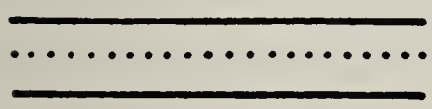
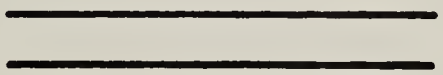
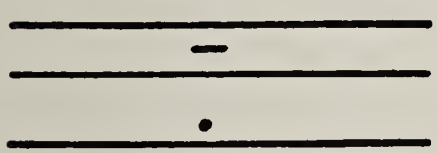
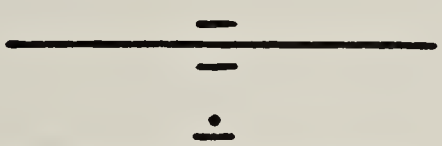
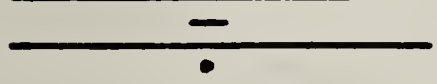
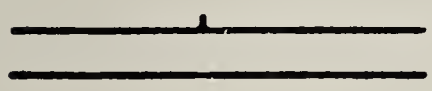
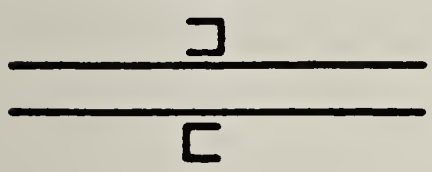
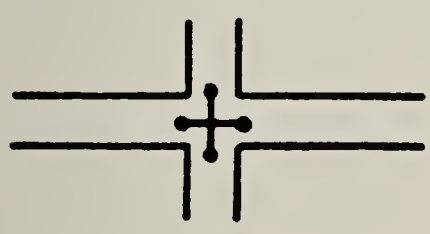
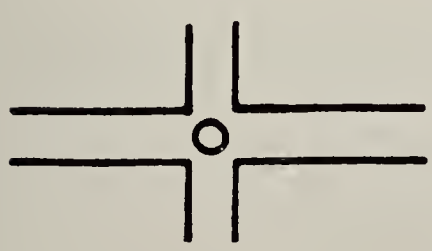
Point symbols, showing top and side views of the symbols.



Nonspecified symbol
Roundabout
Women's toilet
Men's toilet
Traffic lights
Zebra crossing
Nonspecified symbol
Subway symbol
Telephone box or booth
Pillar
Steps
Footbridge
Building with an entrance

The symbols on page 273 are made from the point and line symbols included in the Nottingham Map Making Kit and by the use of a fine spur wheel. They illustrate the possibilities that are available by combining symbols.

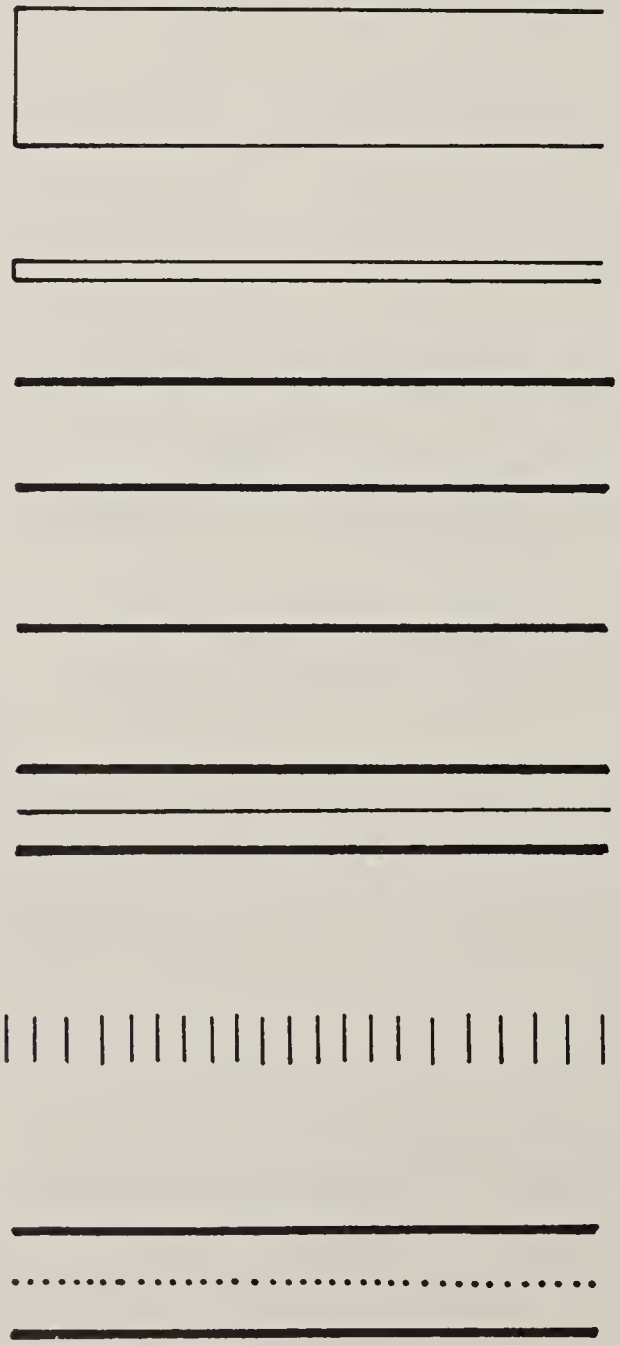
Many of the symbols in the pages that follow page 273 are direct adaptations of the contents of the Nottingham Map Making Kit (the symbols are the same in the new Euro-Town-Kit) or have been greatly influenced by its system of symbols. The symbols in the kit are marked with an *N*. Speakers at the First

Double-Line Symbol	Single-Line Symbol	Use
		Main road
		Secondary road
		Discouragement line
		Dual carriageway
		Footpath
		Railway
		North edge
		Zebra crossing
		Signal-controlled crossing
		Bus stop
		Footbridge
		Subway
		Traffic lights
		Traffic circle

and Second European Symposia on Tactual Town Maps for the Blind, held in Brussels, Belgium (1983), and Marburg, Germany (1985), were convinced of the need to standardize symbols to facilitate travel for some 5 million blind and visually impaired persons in the European community. The symposia adopted several tactile symbols. These symbols, marked with an *E*, are recommended but are not mandatory.

Many of the symbols printed here are in use in various parts of the world. Some symbols are better than others. The use of different media to produce maps has made it difficult to standardize a system of symbols for all types of maps throughout the world (see "Symbols: General Information," this chapter). However, the way you use a symbol, the information surrounding that symbol, and the size and clarity of the symbol will help determine the usefulness of the map you produce.

Symbols for Streets and Roads



Streets and roads on town maps constructed according to the block system: massive, raised surfaces, as opposed to thin single or parallel lines (*E*).

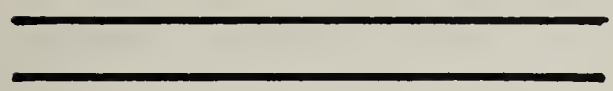
Parallel line street
Main street or road (*N*)

Single-line street (*N*)

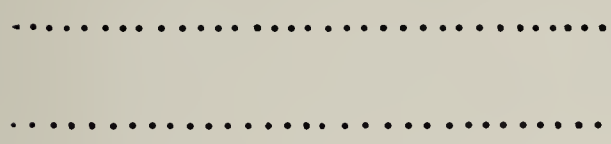
Highway or superhighway

Expressway

Dual carriageway (*N*), double-line symbol



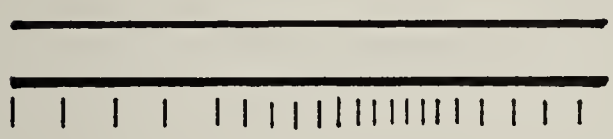
Dual carriageway, single-line symbol



Secondary road (*N*), double-line symbol

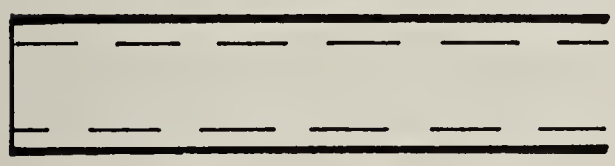
Secondary road (*N*), single-line symbol

Road with slanting embankment (a symbol used on printed maps [Swiss Society of Cartography, 1975])



Variation of the above symbol indicating an increase or decrease in gradation

Road or path using the same symbol



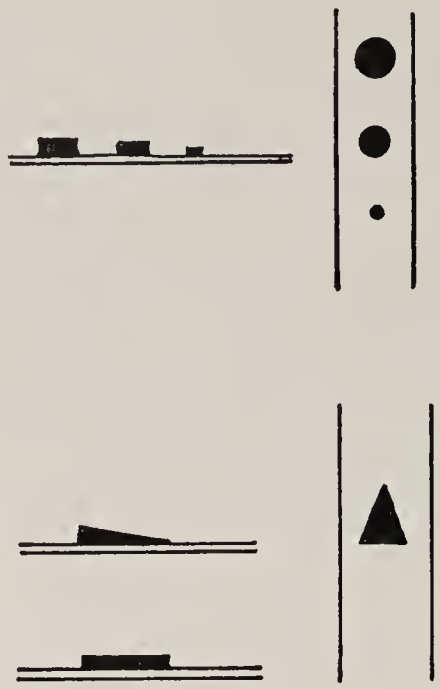
Street with side area, a sidewalk, or a safety lane

Road with sidewalk on both sides

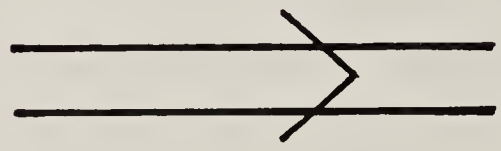
Road with sidewalk on one side

Street with sidewalk, parking places on the north side

Street with pavement, north side recessed



Three versions of a road going uphill

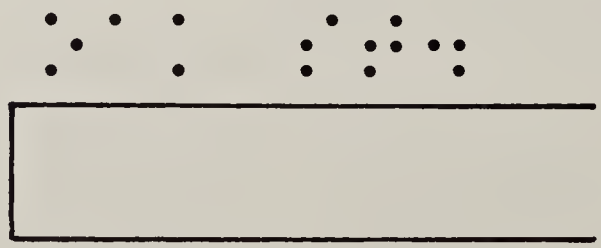


Road with a sharp ascent or descent, depending on the use of the symbol

Street Names

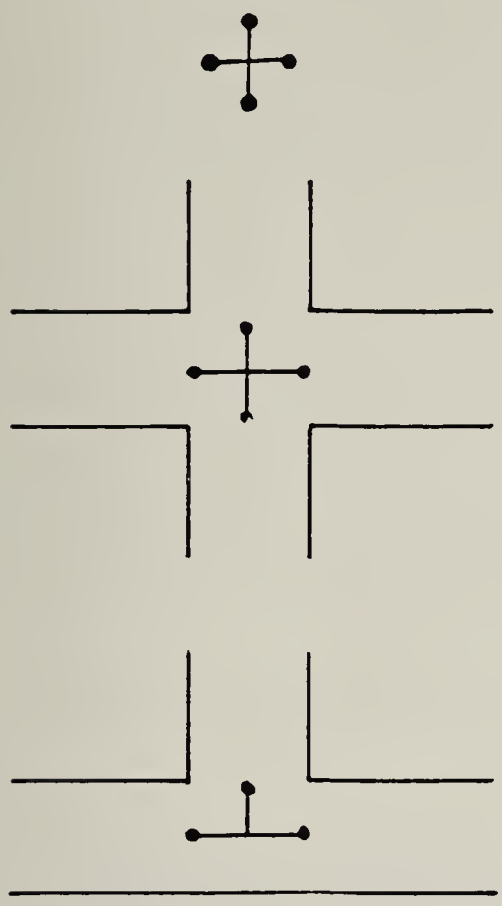
The placement of the name, on top of the street or beside the street, depends on the purpose of the map and the amount of area available for the braille (bus and streetcar routes are often placed on top of the street area)

Oak St.



Street names printed in braille and in inkprint for sighted people (*E*)

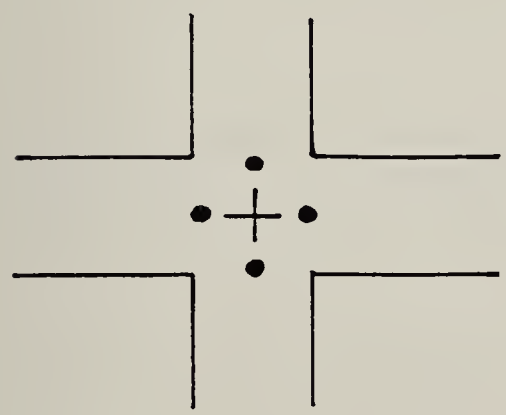
Traffic Lights



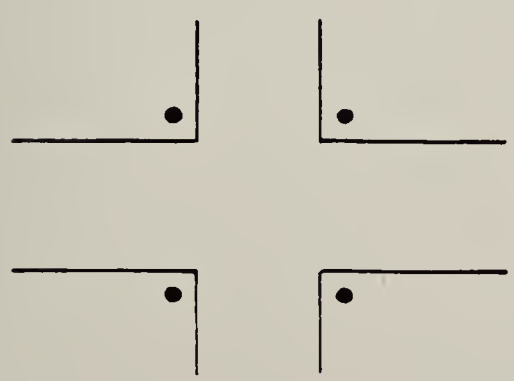
Traffic light symbol (*E* and *M*)

Variation of the proposed traffic light symbol to suit a three-way crossing (developed by Hans-Erich Kiefner, Friedberg, Germany, 1985)

Crossroads with traffic lights, a single-line symbol (*M*)



Adaptation of the traffic light symbol for use on microcapsule paper maps



Crossroads with traffic lights for maps that have bus and streetcar lines within the road area

Sidewalks and Paths

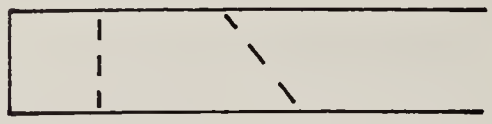
Sidewalk or footpath (*N*)

Pedestrian area between two streets (*E*)

Pedestrian path or walk showing direction (this symbol can also be used as a directional arrow)

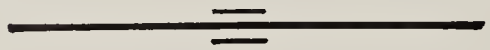
The size of the dot for this symbol can also be increased

Pedestrian Crossings



Pedestrian crossing (*E*)

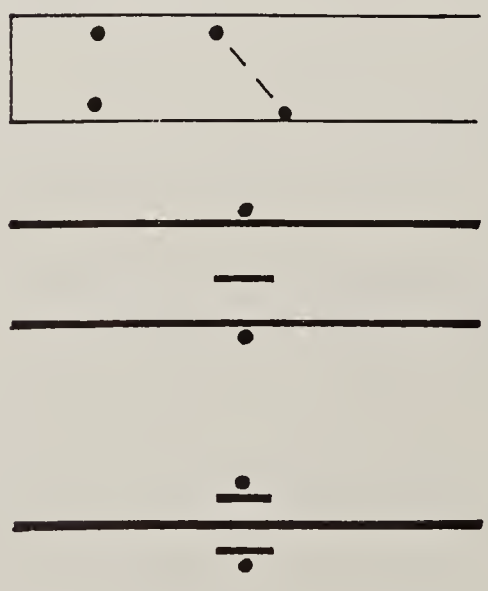
Pedestrian crossing (*E* and *N*), double-line symbol



Pedestrian crossing, zebra crossing, single-line symbol

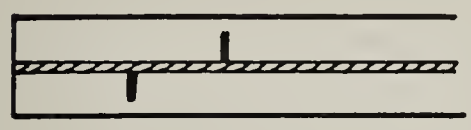
Zebra crossing, block symbol

Zebra crossing, double-line symbol



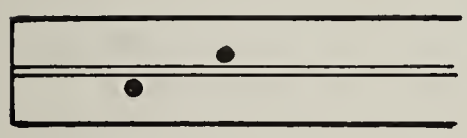
Pedestrian traffic lights are often indicated by one dot when lights change automatically and two dots when lights must be changed manually by the pedestrian (*N*)

Bus and Streetcar Routes



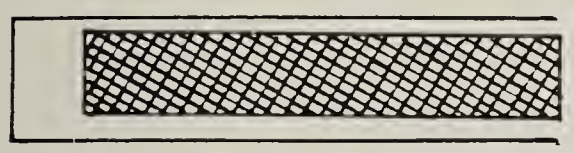
Streets with bus routes and bus stops (*E*)

Bus route with bus stops, double-line symbol (*N*)



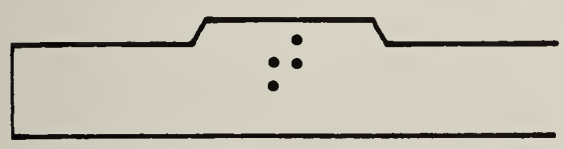
Streetcar routes:
Streets with streetcar or tram routes and stops (*E*)

Streetcar route with stops, single-line symbol



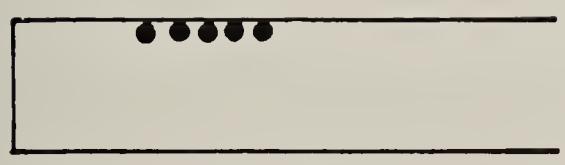
Street with pedestrian precinct (*E*)

Taxis



Taxi stand

Taxi stand

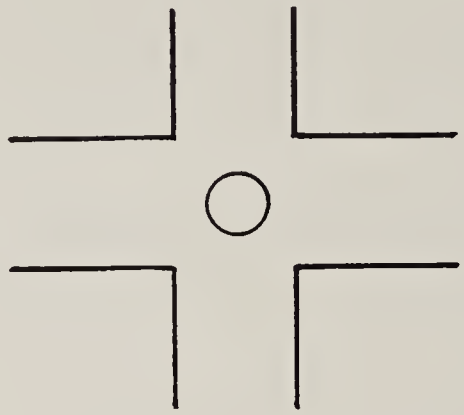


Taxi stand (*E*)

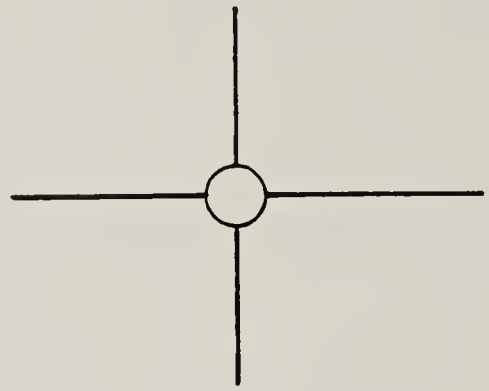
Taxi station

Traffic Circles

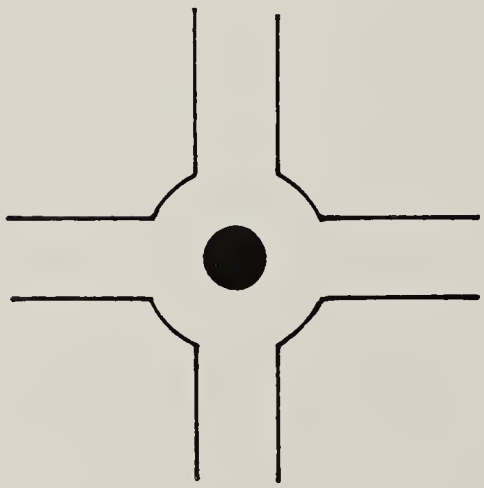
Traffic circle (*E* and *N*)



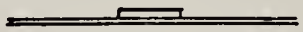
Traffic circle for block roads or parallel-line roads

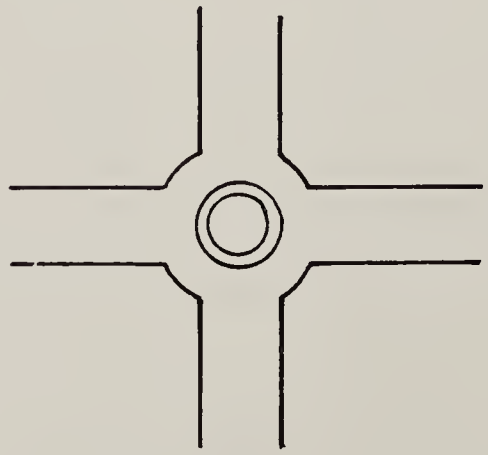


Traffic circle for single-line roads (also called a road-junction symbol)



Large traffic circle with a solid circle center

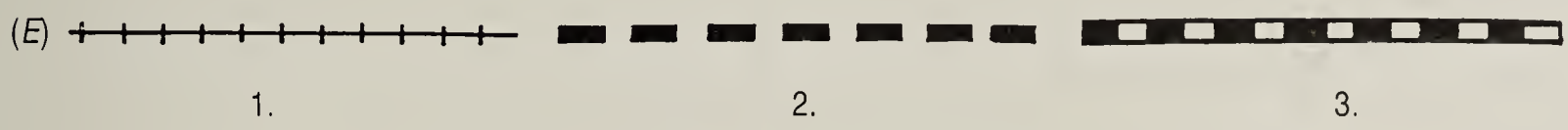




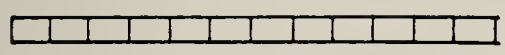
Large traffic circle with a ring center (alternative: two flat disks one on top of the other)

Railway Lines and Tracks

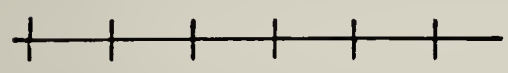
For railroad lines and tracks, symbols 1 and 2 are good on all types of displays. Do not use symbol 3. The white areas between the parallel lines are difficult to feel. The railroad tracks may be mistaken for a vehicle road. This is especially true if the symbol is used on microcapsule paper maps.



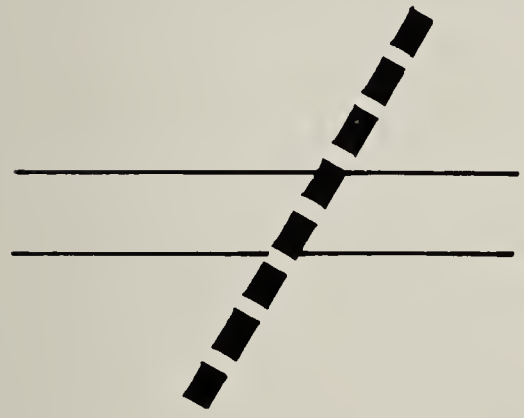
Streetcar tracks (*E*)



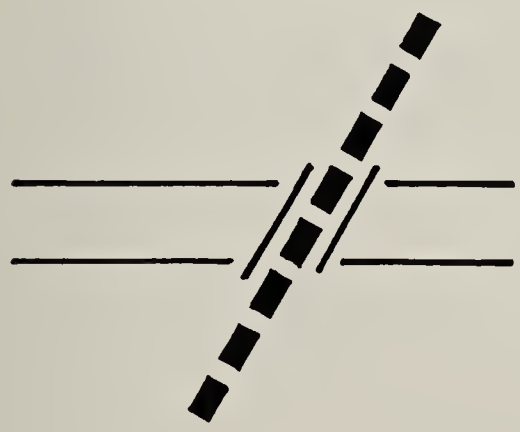
Streetcar tracks on printed maps



Streetcar tracks (National Mapping Council of Australia, 1985)



Street-level crossing, with both the railroad tracks and the street on the same plane



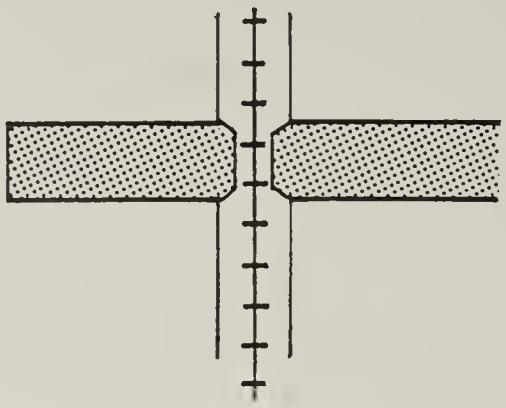
Railroad tracks that pass over the road via a viaduct

Railway station (National Mapping Council of Australia, 1985)

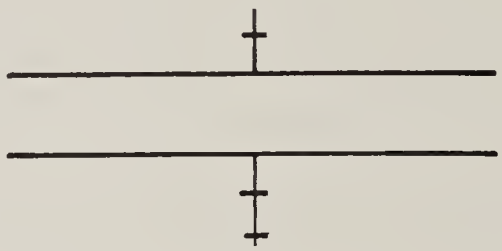
Bridges and Tunnels

Bridge profile

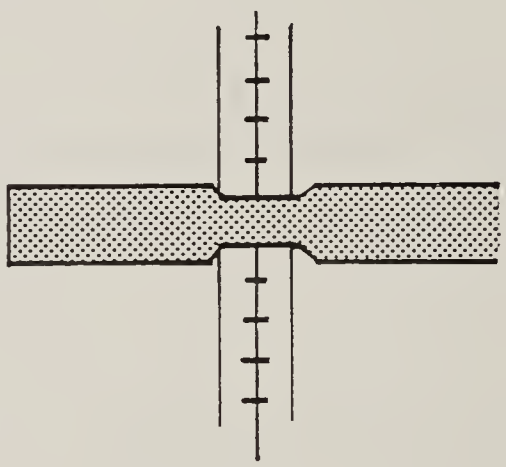
Road



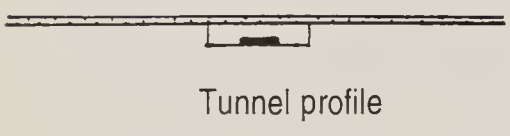
Road passing through a tunnel and railroad tracks passing over a tunnel (*E*)



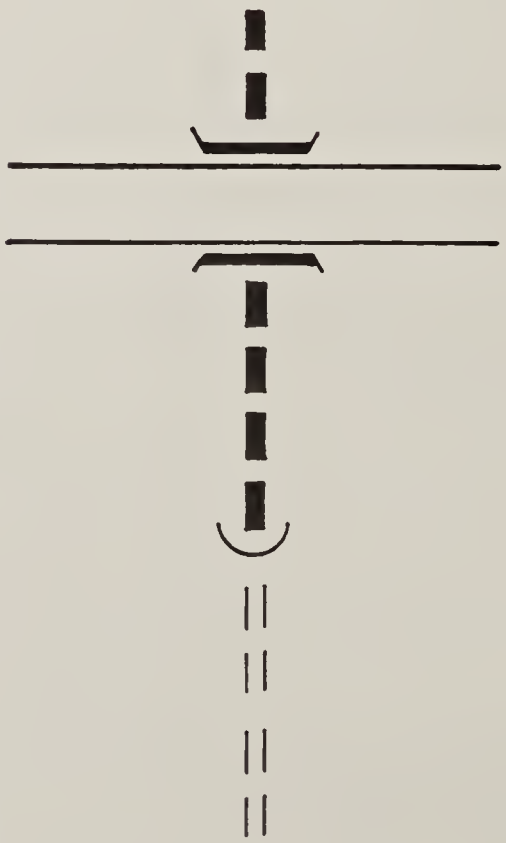
Parallel-line road crossing over railroad tracks



Railroad tracks passing through a tunnel and a road passing over the tunnel (*E*)



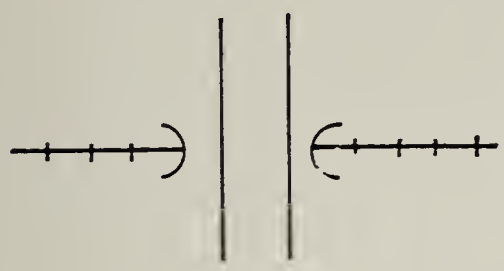
Tunnel profile



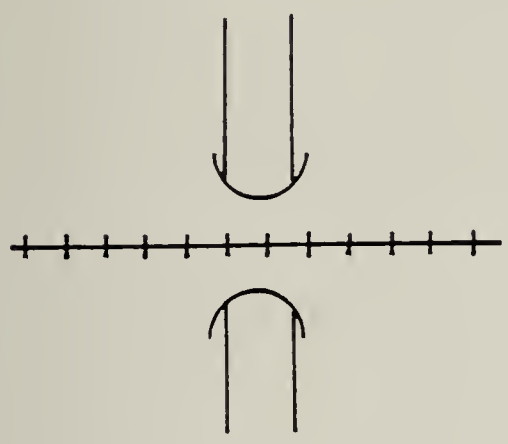
Railroad tracks passing through a tunnel and a road passing over the tunnel

Railroad tracks passing through a tunnel

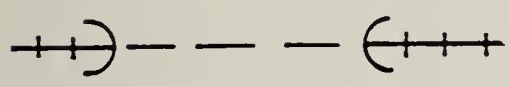
Printed Map Symbols Adaptable for Use on Tactile Maps



Bridge over railroad tracks



Railroad tracks on a viaduct over a road



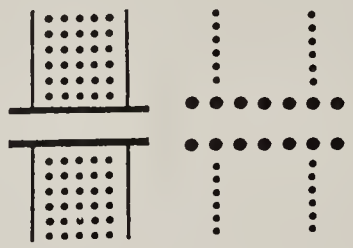
Railroad tracks passing through a tunnel

A road passing through a tunnel, double-line symbol

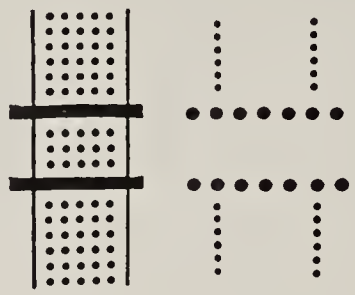
Pedestrian Crossings

Footpath crossing a block or double-line road (*N*)

Footpath crossing a single-line road (*N*)

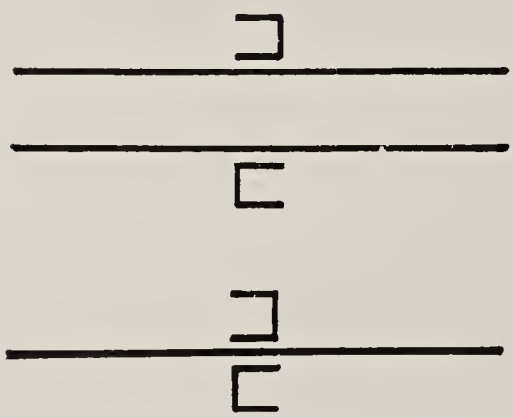


Footbridge

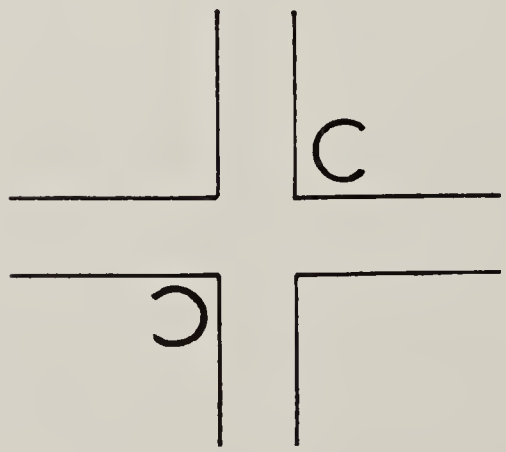


Pedestrian crossing

Pedestrian and bicycle underpass

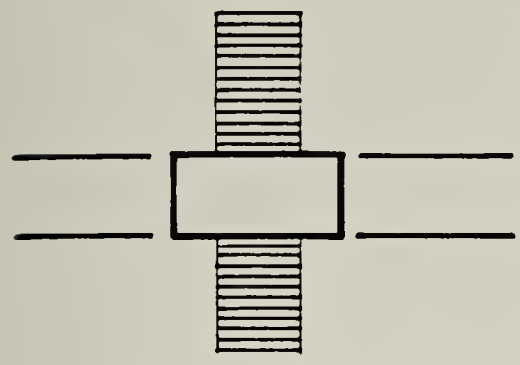


Symbol indicating the entrance to an underground pedestrian passageway (*E*) or a subway station (*N*) (used here with a block or double-line road, or a single-line road)

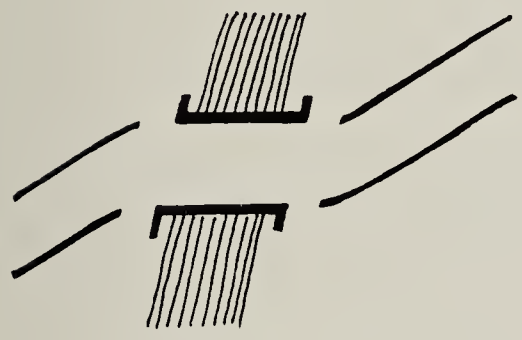


Symbol indicating an underground pedestrian passageway (used here at a crossroad)

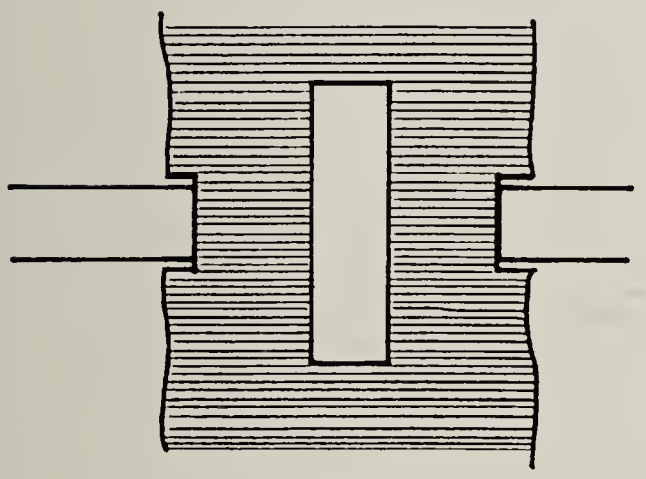
Bridges Over Water



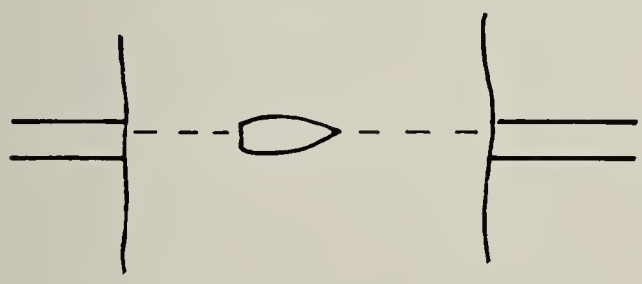
Vehicle bridge



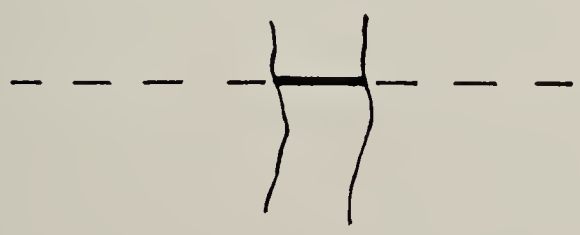
Vehicle bridge



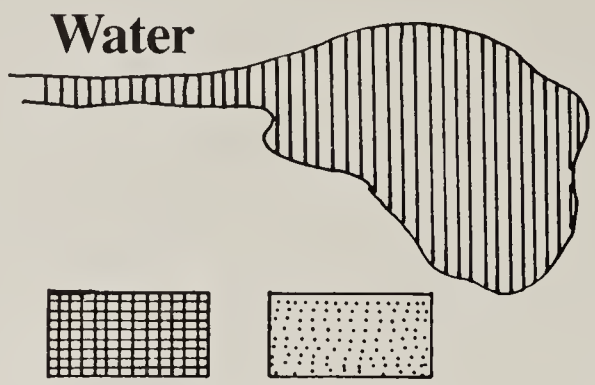
Swing bridge, pivot bridge



Vehicle ferry



Footpath bridge



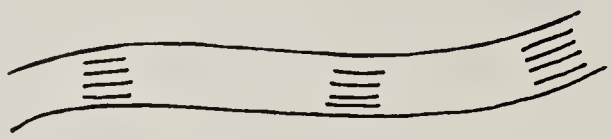
River or lake (*E*)

Water texture

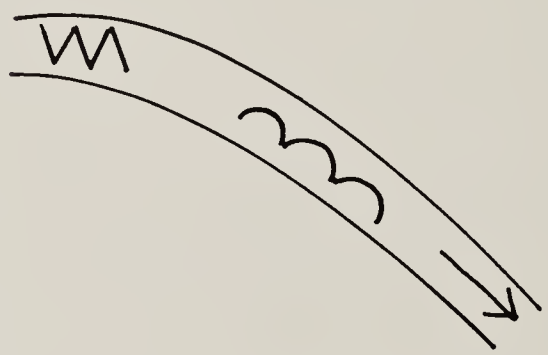
1. Embroidery canvas

2. Pinpricked or dotted area

Waterway or river



Waterfall or rapids (printed-map symbol)



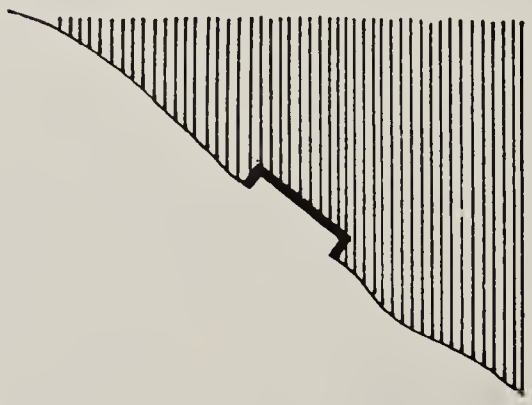
Waterfall

Rapids .

Direction of current

Canal (printed-map symbol)

Canal with a lock and sluice (printed-map symbol)



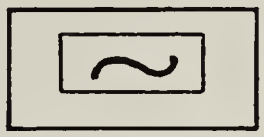
Quay

Buildings

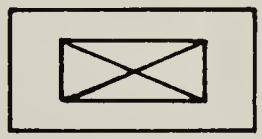
The shapes of buildings are usually based on a simplified form of the actual construction of the building. The following forms show some of the possibilities of using symbols on buildings.

Hospital

Hospital, care center



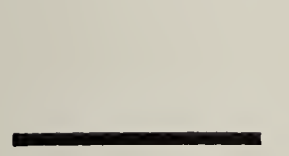
School



Post office

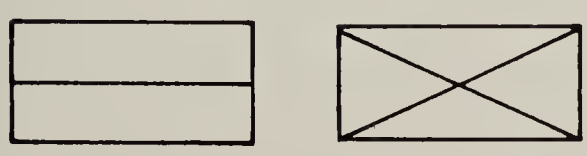
Religious buildings

Church (*E*)

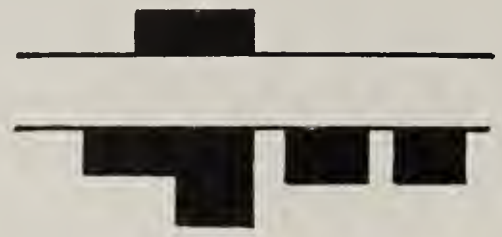


Important building—the function of the building is indicated by one or two braille letters with no accents (*E*)

Exceptionally tall (high-rise) building (*E*)

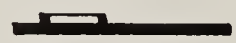


Two house symbols based on the type of roof construction. These two symbols are used on printed maps. *Caution*: post office and house symbols are the same—do not use them together.

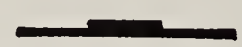


Street with houses

The surface of a building or house is often covered with a low-level texture. This contrast enables the reader to identify it more quickly. Usually, all buildings on the same map are covered with the same texture.



Relief symbols for the entrance or the purpose of the building (post office, school) and braille letters can be felt on top of this texture.



Building entrance indicated by a raised symbol (*E*)

Building entrance indicated by a cutout area (this symbol can also be used as the entrance to a room) (*N*)

Building entrance designated by an arrow

Combination of symbols used in a test conducted by Preiser (1983)

Pictorial or Figurative Symbols

Symbols that indicate stairs, subway stations, toilets, telephones, and so forth and are often a stylized picture of the object they represent are widely used today, and their numbers are increasing. The ability of blind map readers to recognize and

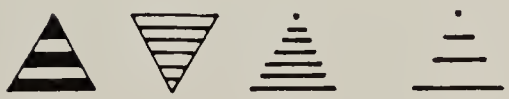
comprehend pictorial symbols is a controversial issue that has not been resolved. How much you use these symbols will depend on how the map will be used and the skill and experience of your readers. However, do not overlook the possibility of using alphabetical code symbols (see "Alphabetical Code Symbols," this chapter).

Stairs

The most important information that a stair symbol can give, other than the location of the stairs, is the direction of the stairs—up or down. The following stairs attempt to show direction. The most commonly used symbol is based on the actual physical form of stairs and is made from layered cardboard.

Stair symbol designed by Wiedel and Groves (1969). The bar indicates the top step and direction of the stairs.

Modification of Wiedel and Groves's symbol by James and Gill (1974). Graduation in height is indicated.



Variation in elevation is vital for directional information. When stairs have only one elevation, their direction must be shown by the direction in which they are pointing. The arrow at the far right is used as a symbol for a ramp.

Escalator up (*Specification for Tactual Mapping*, 1986)

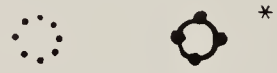
Telephones

Telephone booth (*E* and *N*)

A square frame

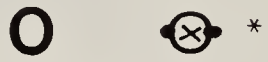
Toilets

Women's toilets



Women's toilets (*N*) (*Specification for Tactual Mapping*, 1986)

Men's toilets



Toilets for men and women (*Specification for Tactual Mapping*, 1986)

Parking

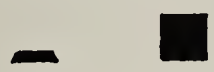
Parking symbol—the international *P* for both sighted and blind readers (*E*)

The general shape of the parking lot should be shown on the map

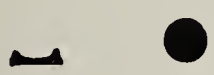
An end, profile view for a solid form

An end, profile view for a line form

Obstacles and Landmarks



Obstacle (*E*)



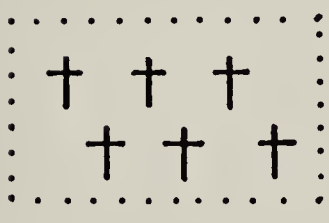
Monument or fountain (*E*)

Pillar (*N*)

Landmark

Tower

Location mark



Graveyard

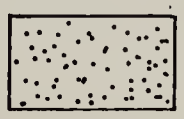
Airports

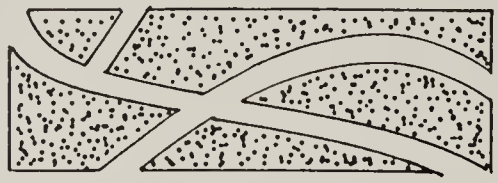
Airport

International airport

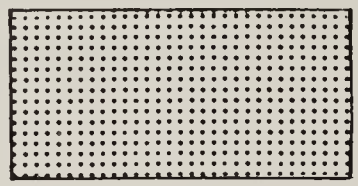
Green Areas

Green areas are made with various grades of sandpaper; the degree of coarseness depends on other textures used on the map (*E*).

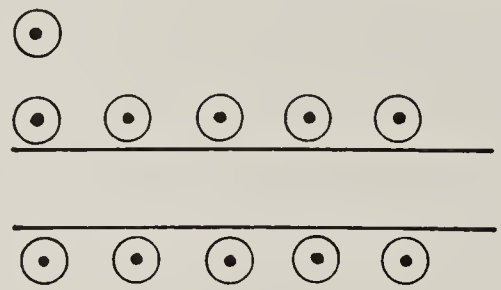




Green area with paths for pedestrians



Park or recreational area with prepared grass, such as for football or cricket fields (Australian symbol for tactile and low vision town maps)



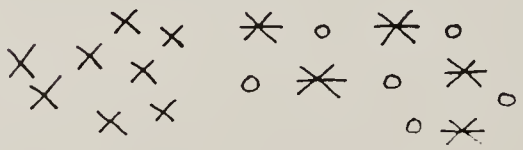
Tree

Tree-lined avenue or road

Tree-lined road, secondary road

Coniferous woodland

Deciduous woodland



Woods or forest

Schoolyard

Grassland

Swampland (printed-map symbol)

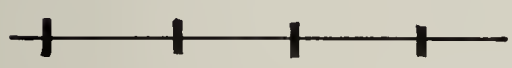
Line Symbols for Mobility Maps

North edge (*N*)

Danger line

Road closed or barrier (*E* and *N*)

Fence



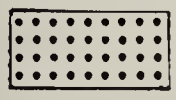
Wall

Prohibited area (printed-map symbol)

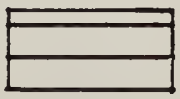
Park, national park, or graveyard (printed-map symbol)

Overhead cable or ski lift

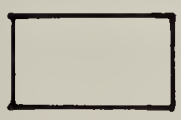
Schoolyard Symbols for Mobility Maps



Grass

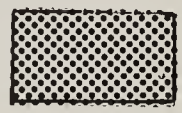


Asphalt



Gravel or sand

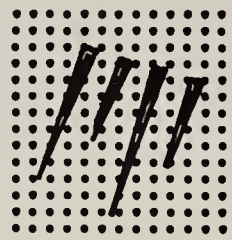
Ceramic tiles or brick area



School buildings

Entrance to buildings

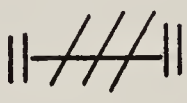
Door or gate



Uphill or downhill slope

Bushes

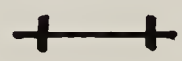
Tree



Bicycle stand

Lamppost

Flagpole



Fence

Ball plank

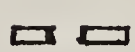
Bar

Sandbox

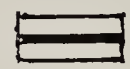
Jungle gym

Play equipment

Ping-Pong table



Benches



Slide

Swings

Basketball net

Cities

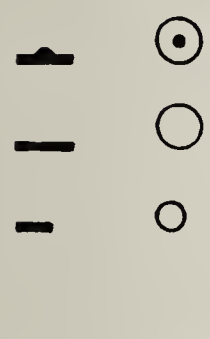
For the following symbols, the numeral 1 denotes symbols used for capital cities, the numeral 2 denotes symbols used for cities with populations over 1 million, the numeral 3 denotes symbols used for cities with populations over 10,000, and the numeral 4 denotes symbols used for cities or towns with populations less than 2,000.

1. Thick cardboard or thin wood, leather, plus a small nail

2. Same base as above

3. Same base as above

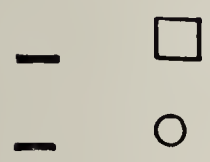
4. Same base as above



1. .23 in. (6 mm) disk with added elevation

2. .23 in. (6 mm) disk

3. .15 in. (4 mm) disk



1-2. All major cities

3-4. All minor cities or towns

City (shape of city area)

Town

Village

Printed-map symbols for population:

More than 50,000

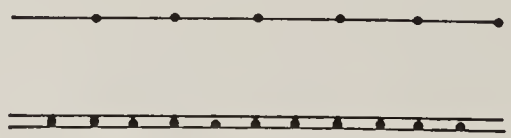
10,000 to 50,000

2,000 to 10,000

Less than 2,000

Boundary Lines

Different countries have different boundary systems for their relief maps. The following lines show several of these systems. For these lines, the numeral 1 denotes lines used for national boundaries, the numeral 2 denotes lines used for secondary boundaries, provinces, and states, and the numeral 3 denotes lines used for community boundaries.



1. Symbol from Nottingham Map Making Kit—north edge

2. Symbol from Nottingham Map Making Kit—danger line

1. Coarse thread

2. Fine thread

3. Correction tong dots made directly on the map or on braille writing paper that has been cut into narrow strips. For microcapsule paper maps, these lines would be made with black ink.

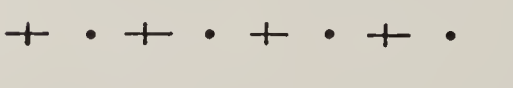
1. Metal wire or coarse thread

2. Coarse thread cut into small pieces (ink lines on microcapsule paper)

1. Coarse, knotted thread

2. Fine, knotted thread

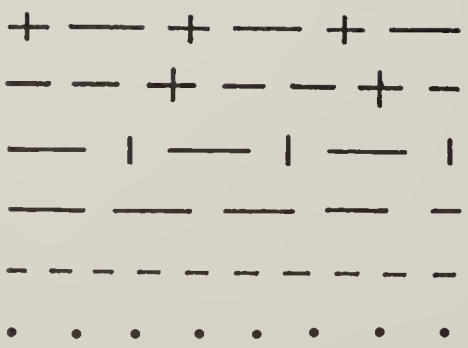
Printed-map symbols:



1.

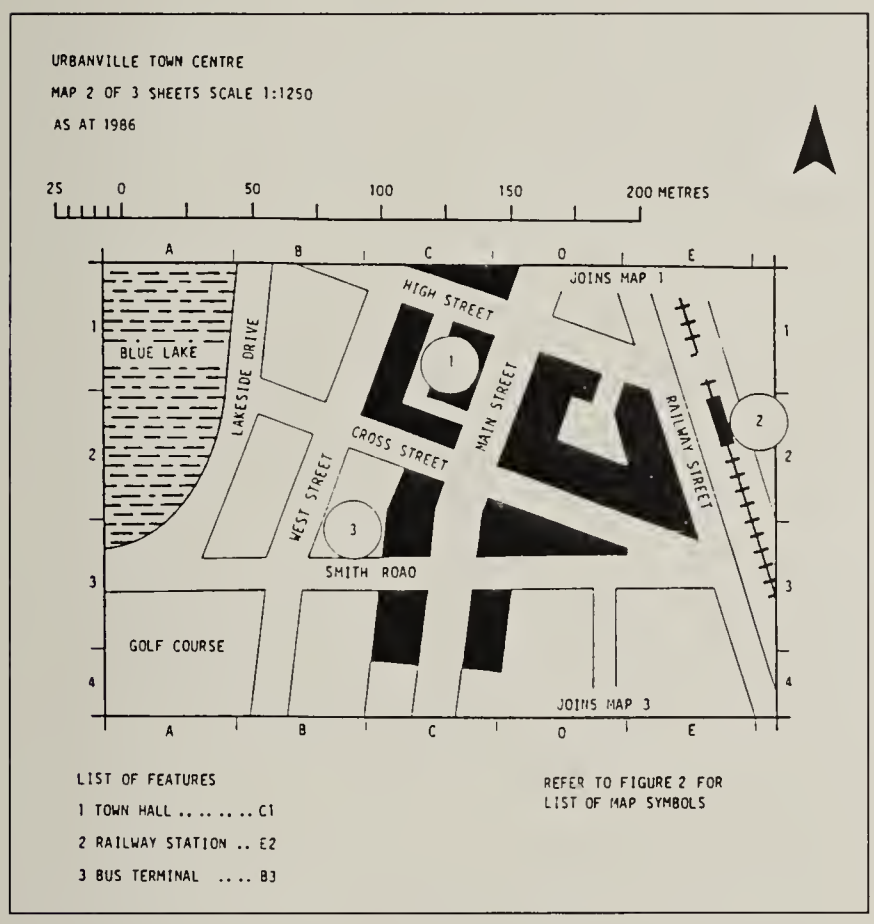
2.

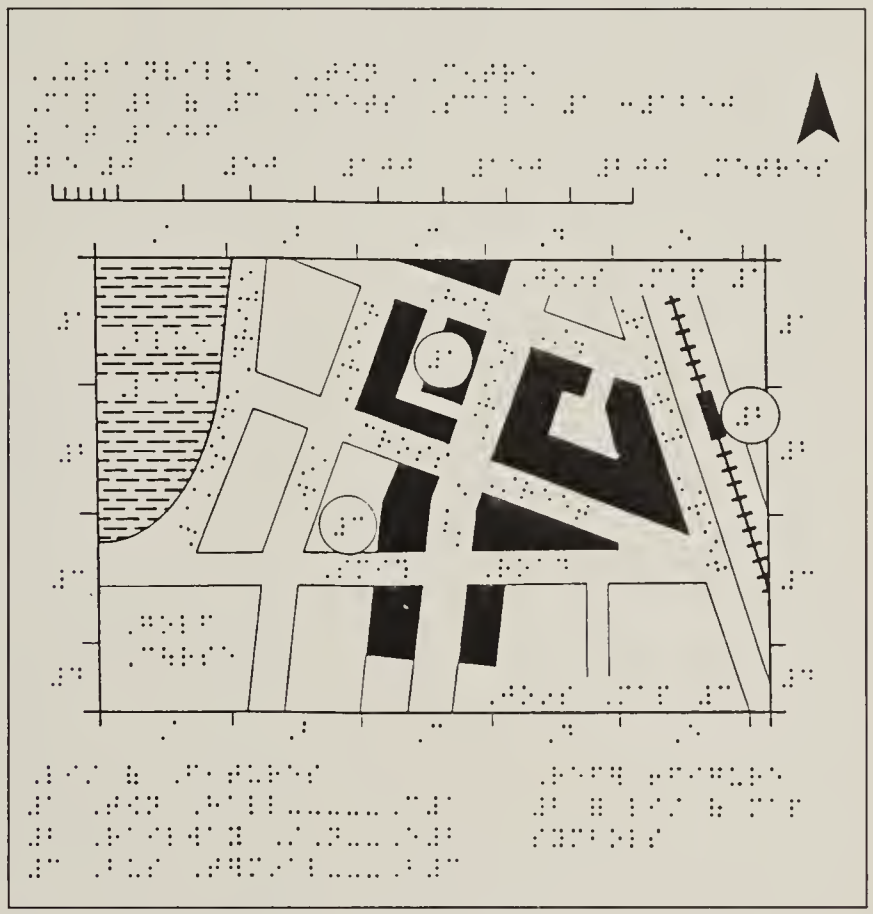
3.



The boundary lines shown on the left appeared on one printed map. So many lines would be confusing to a relief map reader, especially at points where the lines cross one another. If so many lines are necessary on a relief map, make a series of maps to show the areas within these boundaries.

These are a few of the known symbols in use today. There are many more that producers use that are unknown outside the circle of their readers. Eventually, a register of symbols will be compiled. This should give the subject of the standardization of symbols within certain media a firmer base on which decisions can be made on an international level. The map of Urbanville Town Centre and the braille map of the same area shown here demonstrate the use of symbols and labeling discussed in this chapter.





LEFT: In this map of Urbanville Town Centre (National Mapping Council of Australia, 1986), circles were used for the identification of specific buildings. Abbreviations and capital letters are used in the labels.

RIGHT: This braille map was produced on microcapsule paper. The grid index, the scale indicator, and the simple uncluttered presentation of this map make it exceptionally easy for a blind traveler to follow and for a tactile graphics producer to use.

Alphabetical Code Symbols

Research by Preiser (1985) has led to an important finding that many people have suspected for a long time. Preiser noted that figurative symbols in general communicate less clearly than do two-letter codes and raised images. He pointed out that, for example, the tactile map design of the University of New Mexico's Student Services Center shown on the next page is very much like a subway diagram, with dots indicating events or things that can be expected along the path traveled. He concluded that

> Based on feedback from blind subjects in Switzerland and elsewhere, we have totally eliminated figurative tactile symbols and have replaced them with two-letter codes [as

shown in the legend of the University of New Mexico map here]. We have learned that in order to create a mental map in the mind's eye of the blind person, it is not useful to have literal or true presentations of the environment (which is often too complex and confusing), but rather to present highly simplified and schematic topological maps, which are not necessarily to scale.

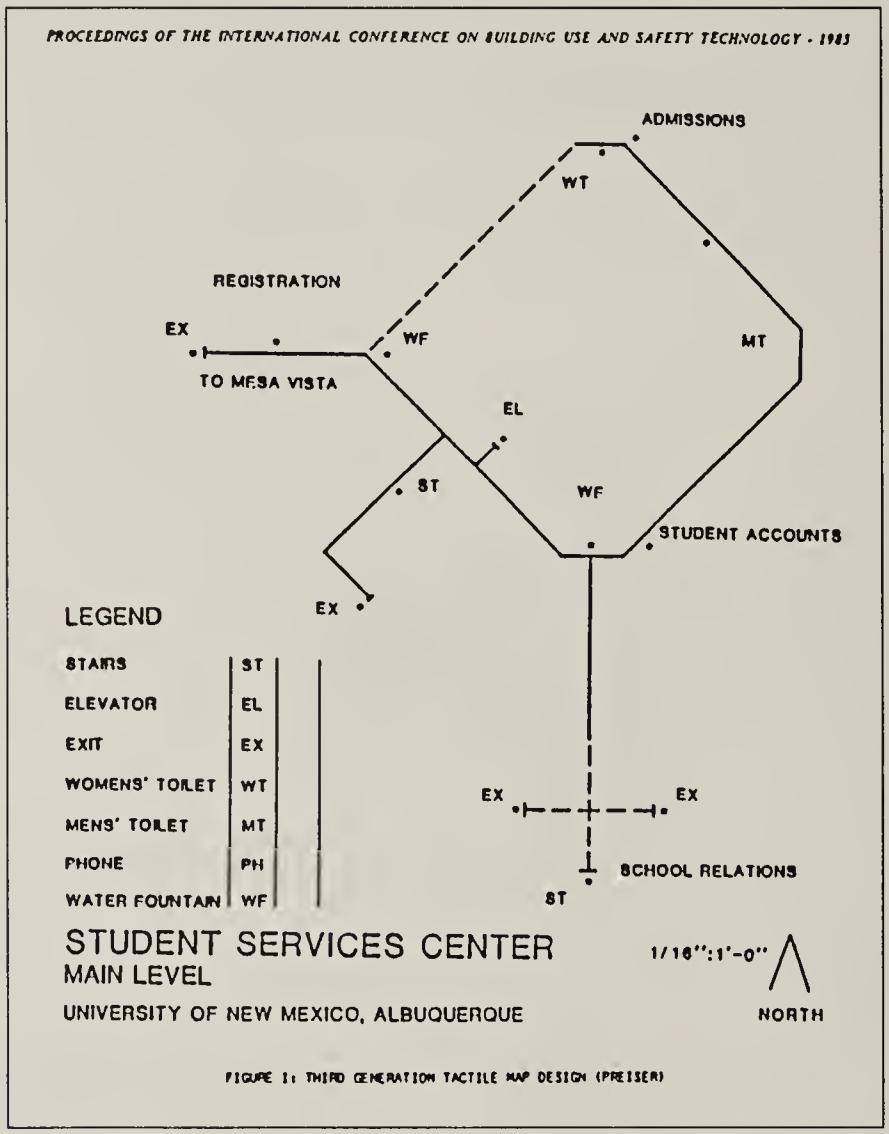


FIGURE 1: THIRD GENERATION TACTILE MAP DESIGN (PREISER)

Creating Your Own Symbols

- Be sure that the new symbol does not feel similar to other symbols that you have already used.
- Symbols can have several meanings. For example, an upside-down canal symbol represents a ski lift, and the symbol for a pillar or column is the same as an obstacle symbol. Check that the meaning of your symbol is obvious to your reader, irrespective of the symbol's position, up or down.
- Keep your symbols simple. The size of symbols varies, depending on the use of the symbols and the scale of the map in which they appear. (Perhaps the use of figurative symbols can be exchanged for alphabetical symbols, as suggested earlier.) For instance, do not use crossed knives and forks to

indicate a restaurant; such details are too small to be understood through touch.
- Be sure that the symbol you use is necessary. Can the information it conveys be explained in the text or the key to the map, instead of your adding another symbol to a map already filled with symbols of various types?
- Review "Symbols: General Information," "Point Symbols," "Line Symbols," and "Areal Symbols," this chapter.

MAP THEORY AND PRACTICE

According to Hans-Erich Kiefner (personal communication, 1983a), one of Europe's finest mapmakers, readers of tactile maps can be divided into three groups, each of which requires a different type of map:

1. People who move independently and are highly intelligent and skillful in using their hands to read and understand relief material. For this group, maps can be complex, even overloaded.
2. Practical people who have gained their ability to orient themselves and to use maps through mobility training courses. This group needs maps that include only the most important elements for self-travel. The maps should be well coordinated, containing neither too much nor too little information.
3. People who have lost their sight in later years and have difficulty with their sense of touch, as well as blind readers who are not able to learn as quickly as other visually impaired persons and who therefore may have difficulty sorting out much information presented at one time. These people must build up a feeling for orientation. Life demands that they too must be able to move independently. For this group, maps should be very simple and should contain only essential information. These simple maps can gradually be replaced by more detailed maps as the reader's understanding of map reading improves. These maps can be made following the step-by-step method.

Map production must conform to the individual problems of these groups. During the production process, make copies of a map in the various stages that meet the requirements of each

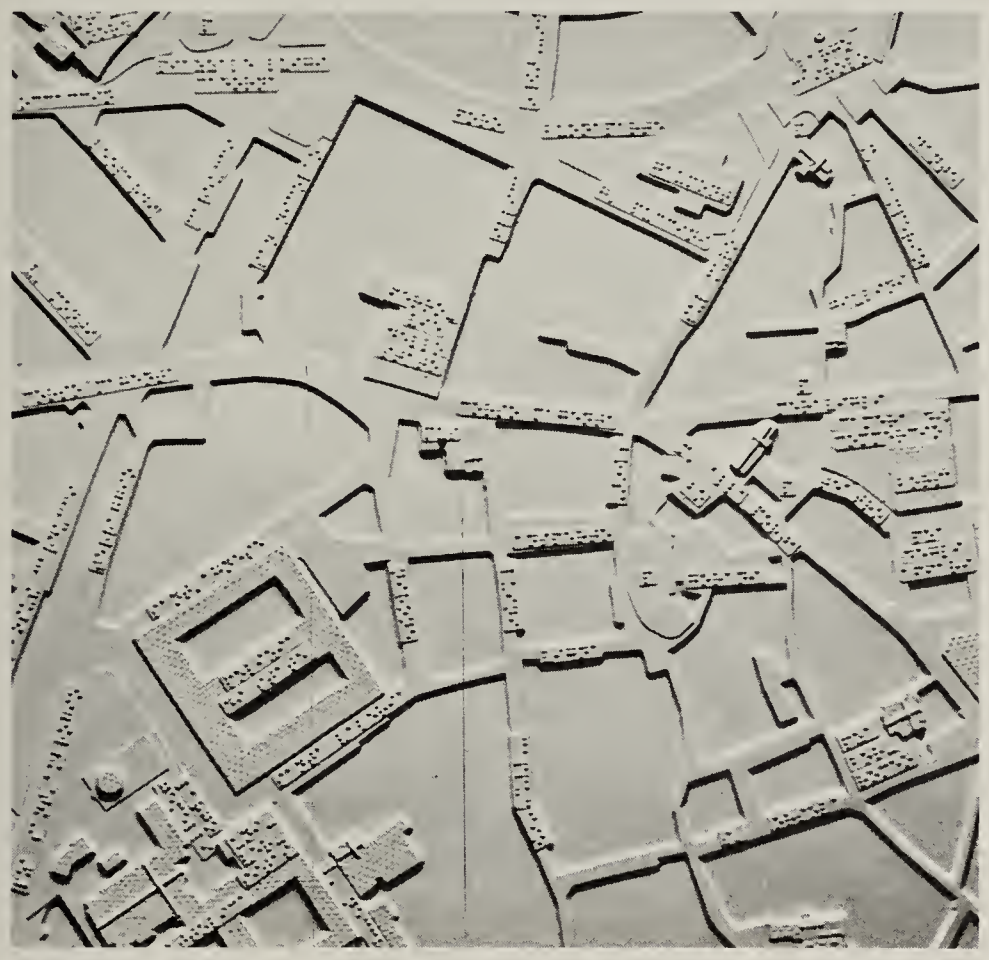
group of readers. Maps produced as part of the Milan Project illustrate Kiefner's comments.

The Milan Project (see A) is made up of a series of maps created by Kiefner that orients readers to various aspects of the city of Milan—its geographic location, its relationship to the surrounding countryside, and accessibility to the city by car, train, plane, and boat—and includes mobility maps covering the center of the city. This project was done for the city of Milan and is a superb example of a complete map project for visually impaired persons.

A. A general map of Milan.

Cities are often spread over a large area. The number of maps required to cover the central portion of a city plus the surrounding area may be great. The Kiefner method approaches this problem by creating a simple, general map of the city that is divided by grid lines (see "Index Grids," this chapter) into numbered areas. This system is often used in automobile atlases or street directories for sighted travelers. Each numbered area is made into an enlarged map. The makeup of these maps follows the requirements of the three groups of readers of tactile graphics.

The simple map shown here (see B) covers a small section of the city of Milan. It presents the main structure of the area. The street system is formed by a block or raised street network. Street names are placed directly on the streets. Pedestrian areas and traffic islands are marked on the various streets. The names or abbreviations of names of buildings are placed directly on top of the building areas. (This map and those accompanying it are from H.E. and E.M. Kiefner's *Reliefkarten* and were made in 1983-84 in Kiefner's mapmaking studio, Wassergasse 13, D 6360 Friedberg / hess. Germany.)



B. A simple map covering a small section of Milan.

The complex map shown on the next page (see C) is of the same section of the city of Milan seen in the preceding map (B). Although the main structure of this more complex map is identical to that of the simpler one, it also includes the following elements:

- The street names are placed beside the streets, leaving the street area free for additional information (streetcar lines, traffic lights, and so on).
- Bus and streetcar routes, route numbers, and stops are indicated on the map, and the location of extra-wide sidewalk areas at the bus and streetcar stops are also included.

- Squares are redivided into green areas so that the sidewalks are clearly marked.
- Subway entrances are marked on sidewalks, squares, and traffic islands.
- Pedestrian crossings are indicated on the streets.
- All pedestrian traffic lights are indicated. Traffic lights for cars are omitted.

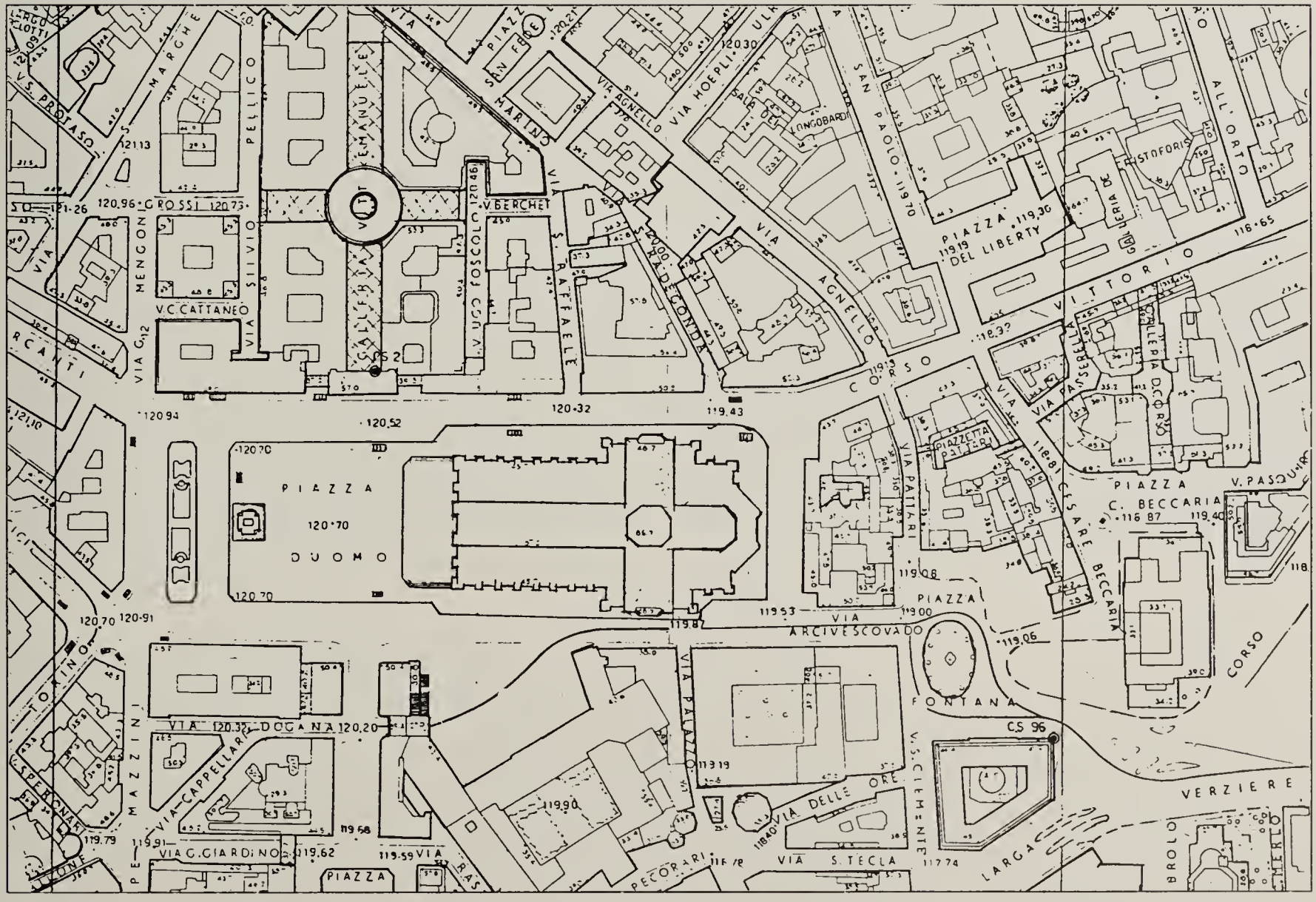
C. A more complex map of the same small area of the city.

- The names or abbreviations of names are placed on top of the buildings. Building entrances are marked.
- The location of taxi stands and telephone booths is shown.
- The direction of stairs (up or down) is indicated.

The map illustrated on the next page (see D) shows the heart of Milan, with its cathedral and shopping center, and is of special interest to all types of travelers. The large scale of the map makes it especially easy for readers to find their way around. This map is based on the original city plan (see E).

The Milan Project also included general or geographic maps of the Italian province of Lombardy, of which Milan is the capital city. The transportation map of Lombardy illustrated on page 304 (see F) shows the relationship of Milan to the

D. The heart of Milan.



E. The original city plan.

surrounding countryside (scale 1:200,000). This map points out the network of highways, canals, rivers, and airports that connects Milan to other cities.

F. A transportation map showing the relationship of Milan to its surroundings.

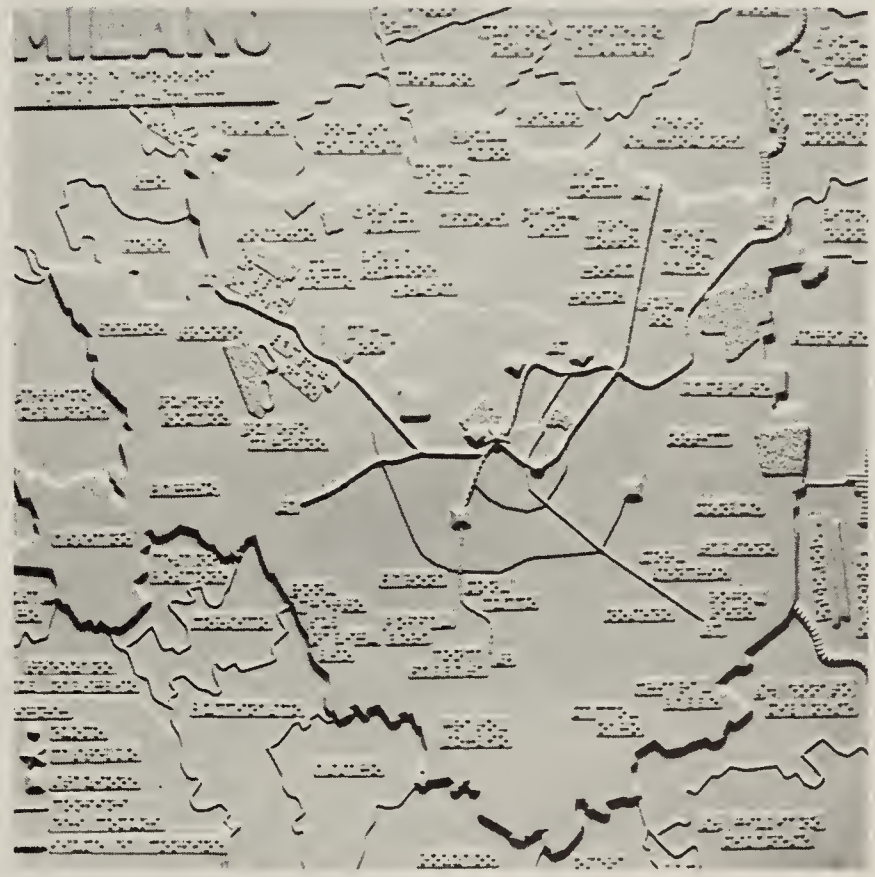
Note that all four of the geographic maps presented here contain a symbol of the cathedral in the center of the city. This provides an excellent reference point for blind travelers. By referring to this recurring point, they have a better chance of relating to the other elements in the maps.

The map illustrated on the following page (see G) shows the outline of the central part of the city of Milan (scale 1:40,000). The large circular form in the middle indicates the ring of motorways around the city. The lines leading into this area point out which highways connect with the ring. Railway lines and stations are also shown. The inner circle marks the center of the city with the cathedral, the Castello Sforzesco, and the Palazzo di Brera.

Finally, the two other maps presented on the following page (see H and I) are a simple and a complex version of a subway map of Milan. They show the lines that connect the cathedral, the railway station, the Castello Sforzesco, the Palazzo di Brera, and the public gardens (scale 1:40,000). In the complex version (I), place names have been added to the area.

G. This map outlines the central part of Milan.

H. A simple subway map of Milan.



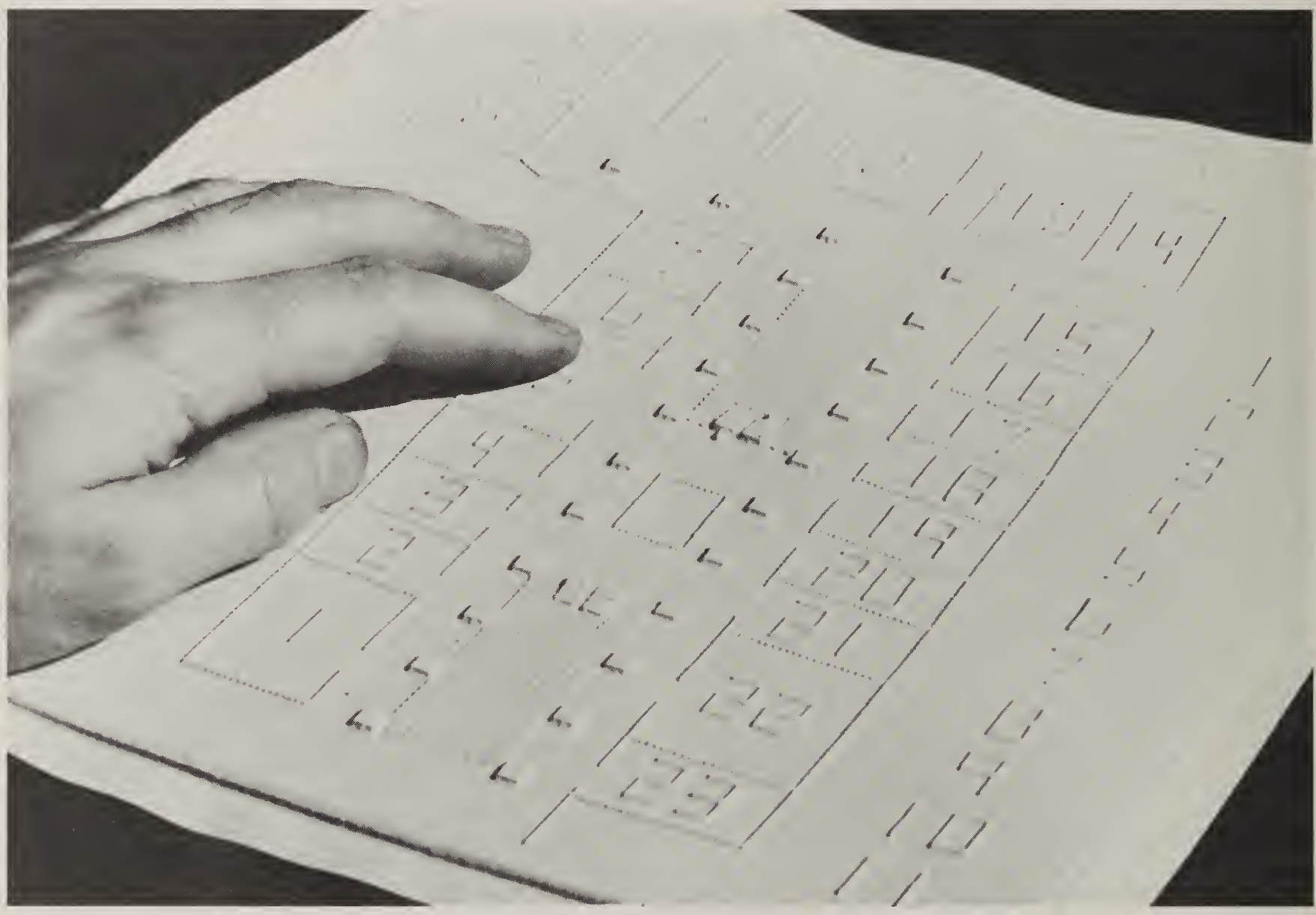
I. A complex subway map of the city.

TACTILE MAPS FOR NONBRAILLE READERS

A great number of blind people do not read braille. Some of these persons are familiar with raised inkprint letters and numbers. These figures can be used instead of braille charac-

ters to label items on a map (see "ABC and 1, 2, 3," Chapter 4). A verbal key, recorded on a cassette, should accompany this type of map.

Illustrated below is a relief map for nonbraille readers who are familiar with the forms of inkprint numbers and letters. For readers who are not able to use either braille or relief inkprint letters, a series of textures and shapes can be substituted for conventional labeling.



The purpose of many of the symbols already in use by makers of relief maps can be easily explained to the reader on a tape recording—for example, "the outline of a square indicates a telephone box." Additional shapes can be created with the cooperation of readers. Make a test sheet of relief shapes and textures. Ask your readers to decide which of these figures is most suitable for a particular purpose. You may find that some of your most clever ideas are not acceptable. When you reach a decision, use those shapes and textures in all future relief maps for this particular group of readers.

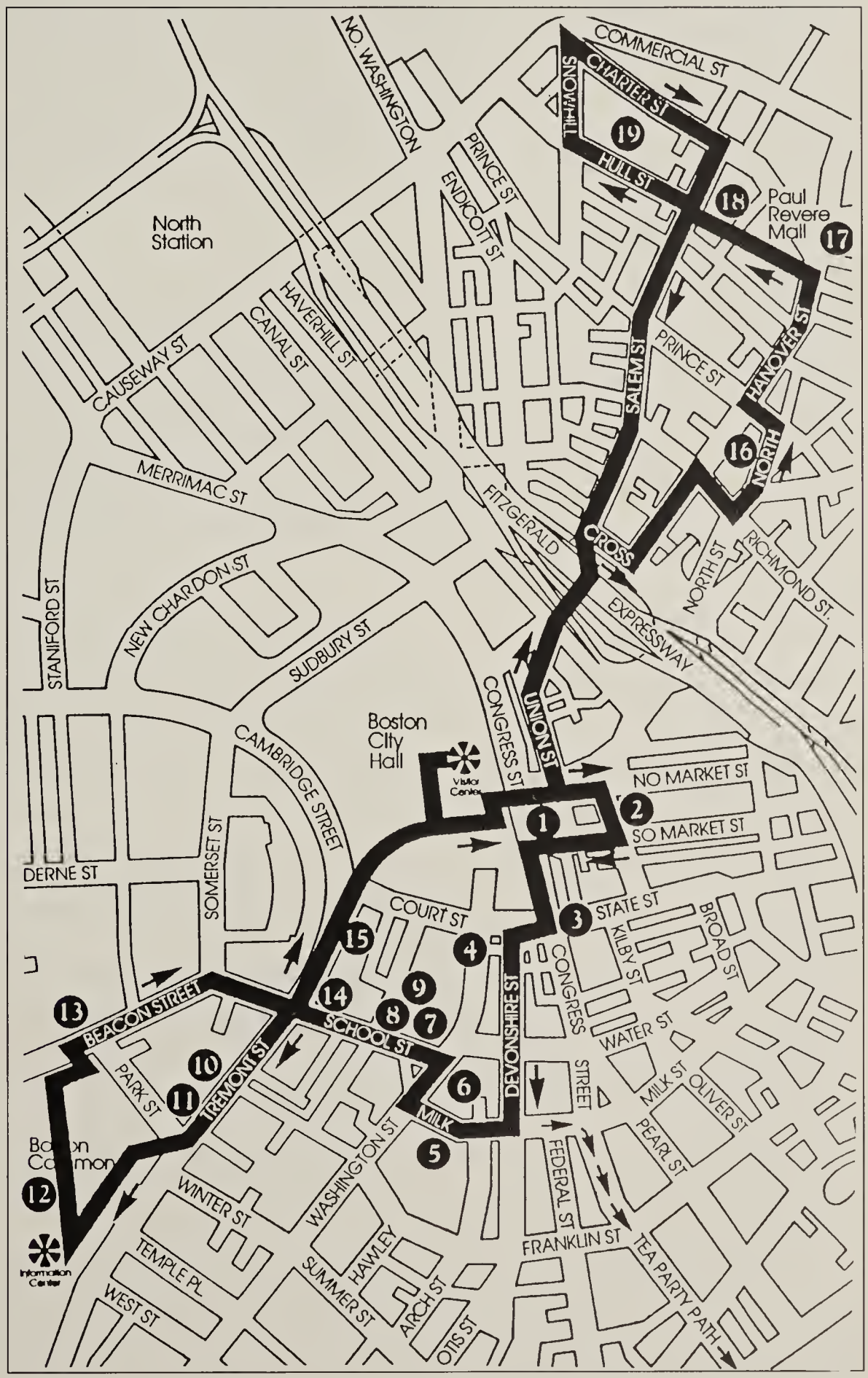
TOPOLOGICAL MAPS AND CHOICE POINTS

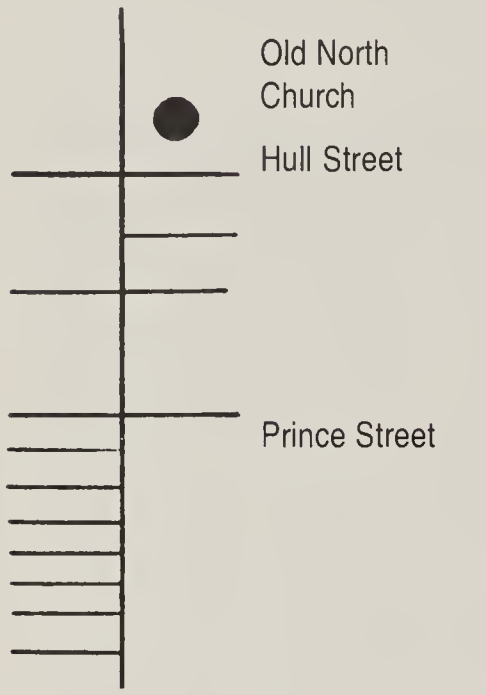
A topological map shows the route of the blind traveler, with all the extraneous details excluded. The information shown is especially related to the needs of the particular person. Scale and distances may vary from the actual ones for the sake of simplicity and readability.

James (1972) commented that the blind traveler judges distance primarily by the time it takes him or her to go from one point to another and the number of landmarks encountered along the way. The uneventful part of the route may be experienced as shorter than the part containing many landmarks. Thus, maps with various scales can be considered.

The dark route on the map shown here is the Freedom Trail in Boston, Massachusetts. The numbers show the locations of important historical sites. The map shown on the next page, made for the blind traveler, is an interpretation of this map. (Note that the second map is only an untested idea.)

The map for the blind traveler can easily be embossed on braillewriter paper by using a spur wheel (see "Embossed Paper Displays," Chapter 2). The lineup of the braille text is not com-





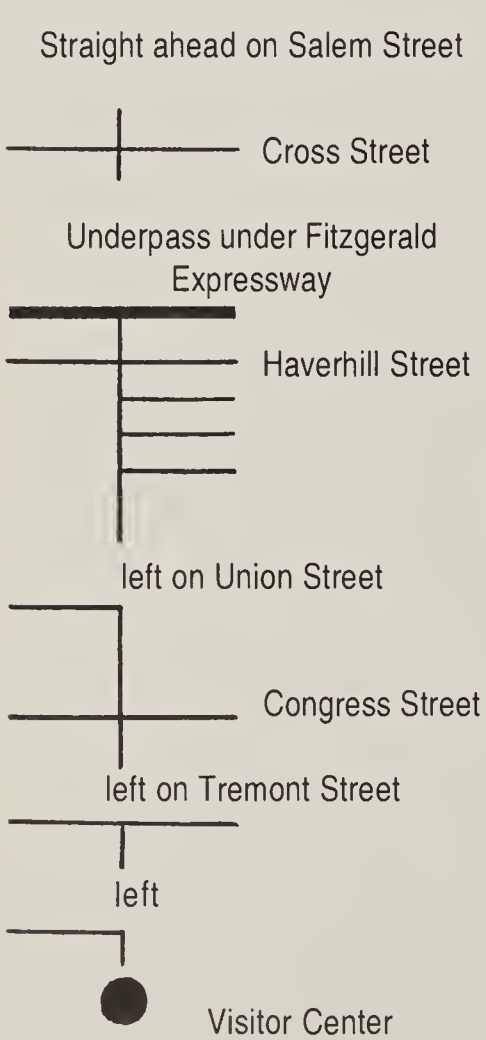
A map made for the blind traveler, based on the Freedom Trail map. The route from the Visitor Center at Boston City Hall to the Old North Church is shown (numbers 1-19 on the Freedom Trail map).

plicated. It can be done on a braillewriter or with a slate and stylus. The map can also be printed on microcapsule paper. Printed on paper, the two maps can easily be folded and put into a pocket.

This type of specialized map, showing only the route from point A to point B, has a definite function for those travelers with a particular goal in mind. It can be compared with a subway map, which bears little resemblance to the actual physical arrangements of the railroad tracks. It displays the information that the traveler needs to make correct decisions about what to do at certain points along the way. The untested possibilities of these maps may lead to a new concept in mapmaking for goal-oriented people.

Choice Points

Choice points are places along a route where a blind traveler must make a choice—to go left, right, or straight ahead. During a discussion held at the Swedish Federation of the Visually Handicapped in Enskede, Sweden, on June 6, 1985, Dr. Emerson Foulke commented on the blind traveler's situation. These remarks provide a good background to this problem:



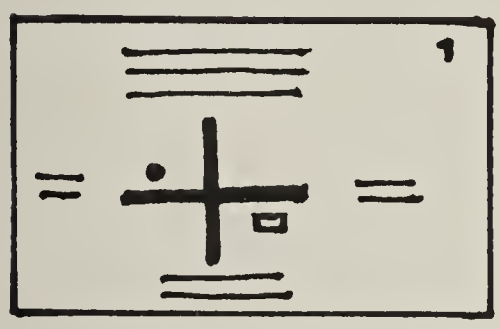
When you operate in a space constructed by humans—such as buildings and cities—you move along carefully laid-out paths in man-made spaces. The solution to the layouts of cities is very often repeated. Almost any city or town will have sidewalks on either side of the street—often with a grassy strip between the sidewalk and the street. Usually, there are rows of buildings arranged along these sidewalks.

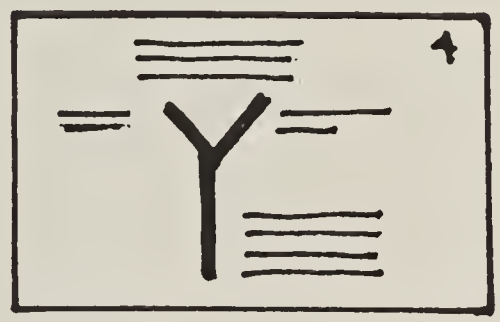
Cities tend to be constructed in very predictable ways. The significance of this, based on memorial representation and the images and information stored in your memory bank, is that it is possible for the blind traveler to make some powerful generalizations about space before ever having entered into it. If you walk into an entirely unknown space of a city, you already know a great deal about that space because of the repetition of the spatial arrangements, spatial structures, that are used over and over again in other cities and towns.

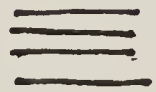
We do not necessarily move at random in space. We move along paths. Paths cross each other, forming intersections. At these points, it becomes necessary to make decisions—a choice point at which you must decide to go ahead or turn onto another path. Space could be

visualized as consisting of a network of path segments and choice points. Blind people encounter these path segments and choice points, and, with experience, they learn routes.

On the basis of these comments, future relief maps may be formed quite differently from the maps of today. They may consist of series of numbered choice points. Information concerning building numbers, objects, changes in surface material, and so forth could be presented in a series of words followed by a choice-point illustration, like the ones shown here. Path segments as connecting lines are no longer important. It is the information that is of interest.







indicates one or several words

This type of travel description could be made on pocket-size cards or on a long length of folded paper, which would make it easy to carry the material along when learning the route. The card system would make it easy to replace part of the series if the route were changed.

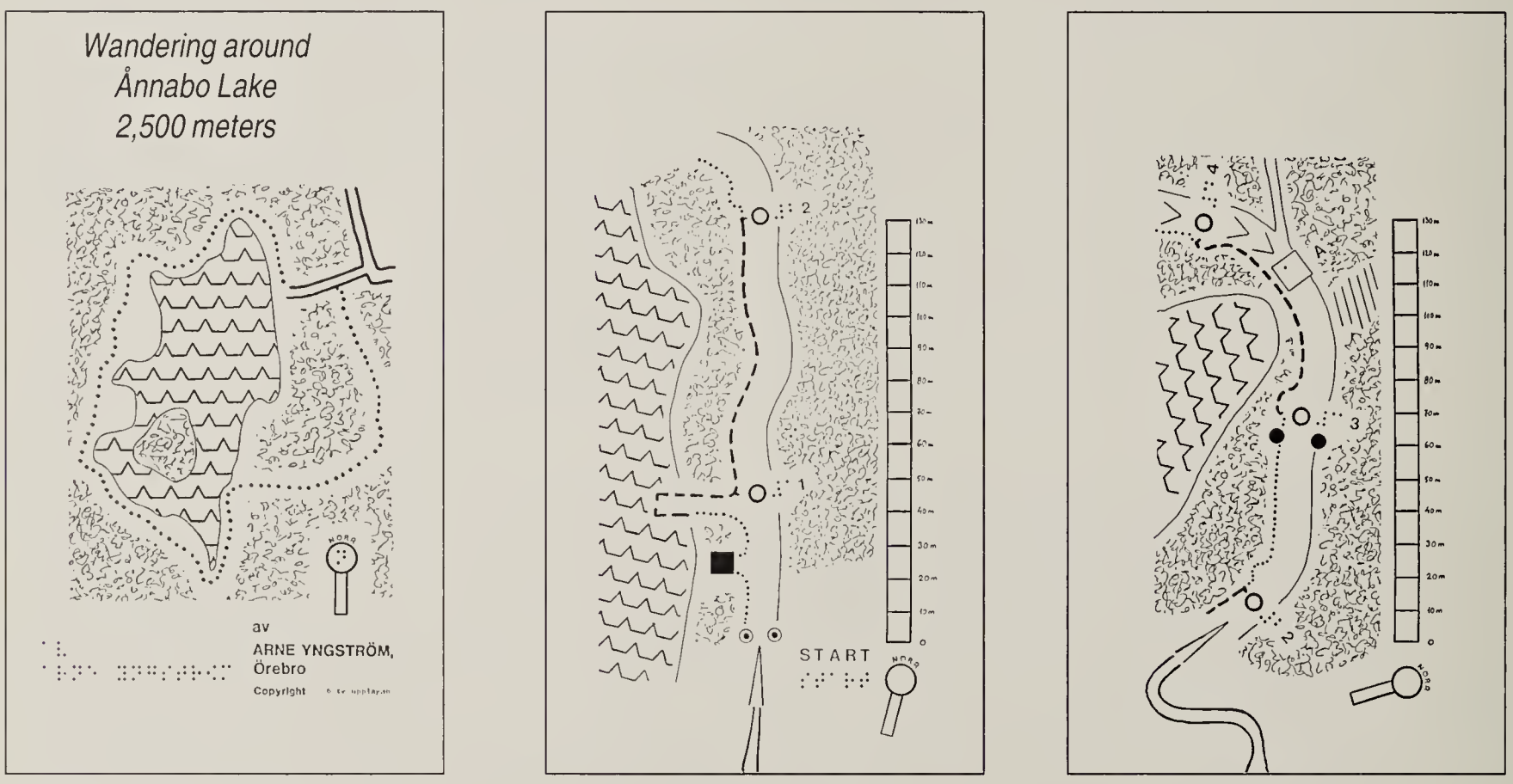
The drawback to this map system may be that the blind traveler would know very little about the content of the space bordering his or her path segments. An orientation map covering the area would give him or her further information, which the traveler might want to have as he or she gains experience with the city and wants to take other routes. The intersections of the orientation map would have the same numbers as the corresponding choice-point illustrations or intersections. Perhaps these numbers could correspond to the grid system on the orientation map.

These comments are just thoughts with which it is interesting to experiment. If nothing else, perhaps they will prompt new thoughts on the construction of maps.

Additional Responses to Particular Needs

The three maps illustrated here are used by blind hikers. They have been well received and are from a much-appreciated relief map book made on microcapsule paper. The book's size, 6.8 in. by 11 in. (17 cm by 28 cm), makes it easy to use in the field. The spiral binding keeps the map series together; pages turn easily and fold out of the way quickly.

The inkprint letters and numbers are purposely hidden in the textured areas. They cannot be felt by blind readers. Their purpose is to give information to nonbraille readers or those with low vision. The scale along the right-hand side of each map is clear and simple to follow.



Unusual orientation maps showing a walk around Ånnabo Lake, from *Vandring runt Ånnabosjön* (Yngström, 1985).

The unusual north arrow that appears in the maps is easily understood. A fingertip fits neatly within the circle. The size and placement of the arrow is consistent throughout the series; the arrow can always be found in the lower right-hand corner. The water pattern is always in an east-west direction, and the tops of the waves point north. This wave symbol is an attempt to create an areal texture that would indicate a direction of the compass.

The directional arrow used in the maps indicates your position and leads you onto the trail. The map used should always be turned so that the arrow points straight ahead. In

this position, the map and the actual surroundings are in complete agreement.

The continuation of the path, from map to map, is easily found by following the double line at the bottom center of each page that leads to the directional arrow.

The circle indicates the beginning or end of a handrail on the left side of the path. Braille numbers corresponding to those on the maps are embossed on the handrails.

These symbols indicate the incline or decline of the path. The symbols are based on the position of skis when the skier climbs uphill or plows downhill .

A mobility map is always read straight ahead, that is, from the bottom to the top of the page. The reader should hold the map in front of him or her in a horizontal position.

This symbol signals a point of interest, indicating that the hiker should refer to the brailled route description.

The filled-in circle indicates large stones.

Yngström, who made these maps, says that the more he works with blind people, the more he reevaluates his maps and changes them to suit the terrain and the traveler. His solutions of yesterday may be outdated by tomorrow—a point to remember!

GENERAL REFERENCE MAPS

General reference maps, which constitute the majority of geographic maps, relate more to needs for information and less to needs connected to physical activity. They do not require as much personal involvement by the mapmaker as does a mobility map. A visit to the country or area in question is not necessary for creating a good geographic map of that area. The comments concerning mobility maps, however, are equally applicable to geographic maps, as are most of the thoughts on all tactile graphic displays. The techniques and solutions are interchangeable.

The ability of the reader to understand relief pictures,

braille, and maps determines the amount of information that can be put into a display. For beginning map readers, a generalized form of the country or continent is a good starting point (see "General Guidelines for Maps," this chapter).

The following are some general suggestions:

- Simplify coastlines to bring out the basic form of the country. Many small islands can be left out, without changing the general impression or sense of the country itself, or it may be necessary to move some of the islands farther out to sea so that the reader can feel each one of them. Here the 1/8 in. (3 mm) rule should be followed: use the minimum distance between symbols for good reading comprehension. Be careful about removing islands when making maps of your own country. One of your readers may live on just the island that has been removed!
- Move items for better identification. Rivers located close together can also be moved apart for better readability. Cities should be kept in their general location but may also be moved enough to be felt as a specific symbol or to allow space for an accompanying braille letter or number. I am not suggesting that you rewrite world geography—just change it a little so that the visually impaired reader can understand the cities, continents, and countries and their relationships to each other. As your readers advance in skill, the maps can become more complicated, but they should never be cluttered or confusing. Several maps containing a variety of information, or a basic map with overlays and underlays, should solve most geographic problems if the student's and the mapmaker's abilities are well used.
- Separate map parts. When you are making geographic maps for young readers, it may be advantageous to make printed copies of your patterns for continents and countries. These copies can be given to the teacher, who will be using your relief map with a blind or low vision student. The teacher can trace these simple forms onto sandpaper, cardboard, or textured paper and use these loose forms to increase the variety of activities and the student's understanding of geography. By adding or taking off a particular area on the map forms or by adding certain areas within a country or continent, the student plays an active role in map reading.

These forms can also be used by the teacher or student as patterns on a raised-line drawing board.

- Attend to form as a whole. Try not to make a map of half a country, area, or city block, unless it is absolutely necessary. Instead, try to find natural boundaries. Give the blind reader a complete form to understand. If there is water around the whole or part of the country or area, extend the water texture to the edge of the map. Doing so avoids the assumption that the water is a limited area along the coastline.
- Concerning the issue of overlap, experience gained from visually impaired map readers indicates that it is easier to understand new relief material if it contains some already-known elements (Hertlein & Laufenberg, 1984). This would suggest that parts of maps should not merely border on each other, they should overlap each other. Overlapping of this kind gives the reader a familiar area from which to start his or her study of the new map.
- "Blank" maps are plastic maps that are created from a built-up master or maps produced on microcapsule paper and are made without a printed text of any kind. These maps can be used by both blind and visually impaired readers. Teachers can add information that suits the needs of their students, including braille or large-print text. This type of map is in demand from teachers of all school grades, as well as from international organizations for the blind, who add necessary information in their own languages to the maps.

A MICROCAPSULE PAPER MAP: A CASE STUDY

The microcapsule paper map of the Trandstrand mountain area in Sweden illustrated on the next page was made by three cartography students—Ann Gustafsson, Karl-Gustav Johansson, and Toresten Hökby—at the Royal Institute of Technology in Stockholm. Three weeks before its production, the students were unaware of the problems of visually impaired people, the use of braille material, and the making of relief maps. The students were given a few basic rules in mapmaking for blind persons. The sparseness of the information given them was intentional, in the hope that their fresh approach,

A microcapsule paper map of a section of the Trandstrand mountain area in Sweden (scale 1:40,000) and the original map produced by the Department of Land Survey (Lantmäteriet) in Gävle, Sweden. The scale of the original mountain map is 1:50,000. For reasons of national security, the map had to be and was officially approved.

The microcapsule map key:

- road
- mountain path
- river
- stream
- elevation curve
- junction of paths
- hotel
- wind shelter
- orientation point (mountain top)
- inhabited area
- ski lift

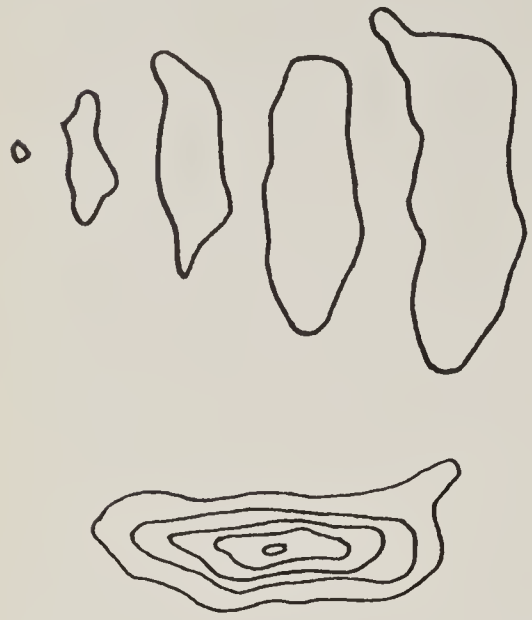
unhampered by traditional restrictions, might bring new ideas to this field.

At first glance, the map they made seems to be an unbelievable clutter of symbols, of no aid to a blind or visually impaired hiker. However, there are several reasons for this appearance. A mountain map without an indication of the various elevations loses its informative value. The hikers could familiarize themselves with the terrain by studying a plastic elevation map before each trip. The students were required to make a map for summer and winter use that hikers could carry with them wherever they go. The students decided to produce two maps—a plastic version that would allow for several elevations and a microcapsule paper version that had only one elevation. The plastic map could not be easily folded; it would be studied at home base. The microcapsule paper map could be folded and carried in a pocket; it would be taken into the field.

The original printed map was changed from a scale of 1:50,000 to 1:40,000. The size of the relief map would be 11.69 in. by 16.54 in. (297 mm by 420 mm), which is a standard A3 paper size.

The original for the relief map was drawn with black ink on transparent drafting paper, which was laid on top of the printed map. Text was added to the map by using dry-transfer braille characters. Symbols were made according to their use. Several of the symbols were adapted from those used on printed maps: elevation curves, wind shelters, texture for populated areas, and a symbol used on charts to indicate water pipes or oil lines. This last symbol was converted to show the direction of a small stream and fulfilled my hope that the students would use a symbol unknown to relief maps. This symbol has since been used, not in its original capacity but as a directional arrow or a pedestrian path going in a particular direction.

The symbols created for microcapsule paper maps must be large enough, distinct enough, and shaped with enough contrast to be easily identified and understood. The ring shown at the junction of the various paths in the map shown here was born of necessity. It was found that a blind hiker who was following one path on the map would continue onto the next path without realizing that he or she was on the wrong path.



The circle would make the hiker stop and consider which direction he or she should follow. Fortunately, blind and visually impaired hikers carry a special compass for their needs, and the circle symbol proved most useful to them.

When the master for the plastic map was produced, many copies of the original printed map were made in an office copying machine. These maps were mounted on cardboard and cut into sections according to particular elevation areas, as illustrated here.

One of the original printed maps became the base on which the various sections of the map were mounted, one on top of another, until the actual elevation of the area was reached, as in the example shown here.

Mountain paths made of knotted, coarse thread were added to the landscape. Populated areas were made by embossing braille paper with correction tongs, orientation points were indicated by small nails, and the river was made of sandpaper. (The students had no idea that sandpaper is the acknowledged texture for green areas on mobility maps. To the hikers, the texture made little difference, because the key stated that this texture was a river symbol.) The last step involved putting the master into a vacuum-forming machine to produce plastic copies of the elevated map.

For best results, irrespective of the map area (a country, a mountain, or the inside of a building), the producer should work closely with the people who will be using the material. These students clearly demonstrated that relief material does not have to be made by "experts"—they progressed from the unknown to a workable map in three weeks!

THEMATIC MAPS

Thematic maps present qualitative or quantitative topical information: population, climate, or agricultural, political, and economic data, to name a few of the possibilities. Symbols are used in these maps to represent different types of information. A single symbol should stand for a definite amount of a particular factor or variable: 1,000 people, 10 trees, 100 acres of wheat, and so on. Symbols can vary in size, depending on the information they represent. Remember the 1/8 in. (3 mm) rule: Leave that amount of space around each symbol so that

the symbol can be recognized and understood for what it is.

The symbol, the object it represents, and the quantity or quality of that object should be pictured and described in the key to the map. This key should contain all symbols, including the various sizes within the same symbol family, and the descriptions of their respective data.

Dots

A single dot can represent a hundred or a thousand or more people, industries, farms, and so forth. A series of dots, graduating in size, can represent an increasing amount of population or other types of information:

100 trees,

1,000 trees,

10,000 trees.

Do not use dots for quantitative information on maps where the location of particular cities is marked with a dot. Choose another symbol.

Circles vs. Triangles and Squares

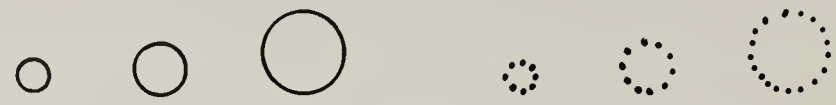
The circle, square, and equilateral triangle are the most frequently used point symbols on thematic maps. Their size, constant or graduated, depends on the information to be presented.

Tests with visually impaired readers show that the circle is preferred over the square or the triangle (see Thompson, 1983). The circle has many advantages. Tactilely, it is the easiest geographic form to recognize (Meihoefer, 1969). A change in a circle's position will not alter its shape or tactile appearance. However, a square , when given this position , becomes a new symbol (Thompson, 1983). The different positions of the triangle are also experienced as different symbols.

The Character of the Symbol

The texture of the outline of the circle, square, or triangle can vary from map to map.

The type of outline should be the same for all symbols of the same family in a graduated series on the same map.



Be consistent. If a particular symbol represents the same object and quantity on a series of related maps, that symbol should have the same appearance throughout the series.

The use of outline symbols or solid symbols (symbols filled with a texture) is dictated by the choice of the map and the information to be displayed. One type is not better than the other. You must make the choice when working with the material at hand.

Size of Symbols

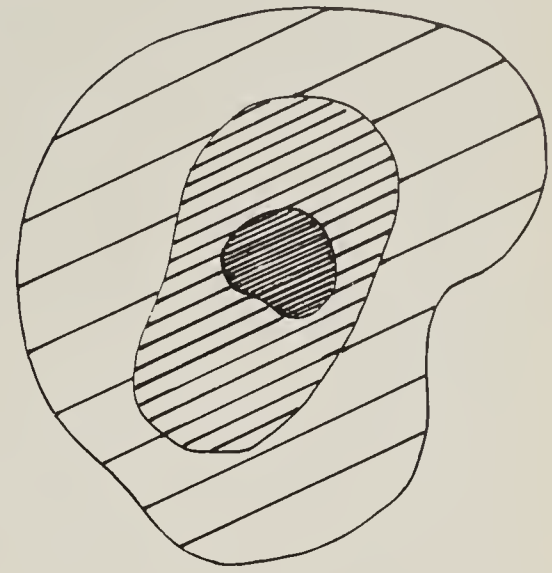
There is no formula for determining the size of symbols on a thematic map. Size is often governed by the scale of the map on which the symbols appear. Thematic maps are usually made on a small scale because of the scope of the information that is to be displayed. Thus, certain areas would have a concentration of symbols that might be difficult for the reader to discern.

The following are possible solutions:

- Decrease the number of symbols from the inkprint material and increase the quantity of data for each symbol.
- Use graduated sizes of symbols within the same family. When doing so, be sure that the difference in the sizes of symbols is large enough to be felt easily. There should be a greater difference in size among the larger symbols than among the smaller symbols.
- Test the size of various point symbols with your readers. Work out the graduated sizes on a series of tested circles or other symbols. Keep the results on file for reference, along with your other information on symbols (See "Symbols: General Information," this chapter). All readers do not have the same capacity of discernment. Try to learn the ability of your readers.
- Several maps may be better than one map if several types of information are to be compared. Small point symbols of

various types, crowded within a small area, are difficult to differentiate.

- Point symbols may not be the best solution for a particular map. If in doubt, try areal symbols. You do not have to copy the layout of the inkprint textbook if you feel that there is a better way to present the information to a specific group of readers.
- Graduating the intensity of a pattern, as shown here, could indicate an increasing density of population, industrial activity, and the like, provided that the character of the areal symbol that is used is kept the same.



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CHAPTER 7

Making a Tactile Graphic Display

At this point, you have already decided on the production method that you will use, on the basis of your evaluation of the number of readers of your display, their ability to read braille or inkprint, their familiarity with relief material, the place where they will use the material, and so on. You have also read through the previous chapters and know some of the things that can and cannot be done with the various parts of a tactile display. This chapter deals with several ways to proceed from a sketch to a master and comments on such topics as editing printed material for relief displays, changing the size of the printed format, selecting materials used in making a master, and changing or adding information on various kinds of masters and on plastic and microcapsule paper copies that have already been produced. The word *sketch*, used loosely here, refers to all two-dimensional graphics: pencil sketches; ink drawings; printed pictures; maps, diagrams, and graphs; and illustrations from books and newspapers.

OPPOSITE PAGE: Simply raising the elevation of the elements in a display does not ensure its success. Careful editing and consideration of the elements are essential.

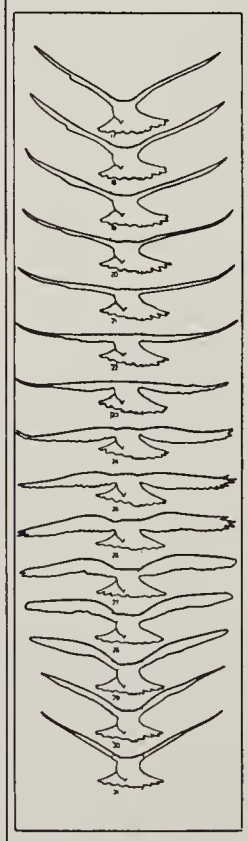
EDITING

Editing is an essential step in making a tactile display. Without proper editing, inkprint material—although fully understandable to a sighted person—may be incomprehensible to a blind person when it is presented in relief. Simply raising the elevation of the elements in the display does not ensure its success. It is almost like raising your voice to a deaf person in an effort to have him or her hear what you are saying.

With the help of the guidelines for pictures, maps, and diagrams that have already been presented, you should now be able to edit inkprint material satisfactorily. All unnecessary details, including shading and perspective, should be removed. Your readers should be lead through an uncluttered layout by a natural sequence of elements. Reading and understanding relief displays should be rewarding and stimulating, not tiresome and confusing. Each of the examples that follows in this chapter illustrates a point in editing. These displays can be made as built-up reliefs, masters for vacuum-formed plastic copies, or drawings from which microcapsule paper displays are made. The production methods may vary, but the principles are always the same. Like others throughout this book, these examples are taken from my work in Sweden. Any text accompanying original illustrations therefore appears in Swedish, and the braille shown is based on Swedish text.

Simplification

The article from a Swedish newspaper illustrated here shows the wing positions of a hawk in flight. The picture was made from photographs, with 100th of a second between each



Schematisk bildsekvens från höghastighetsfilm av ryttlande falk, som läses uppifrån och ned. Det är en hundradels sekund mellan varje bild. Falkhuvudet hålls orörligt hela tiden.

Korta pauser hemlighet i tornfalkens jaktteknik

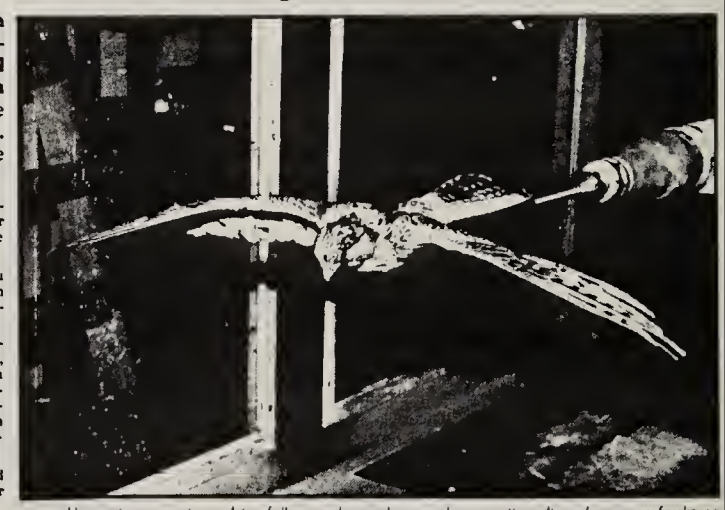
Tornfalken är en av våra få fågelarter som specialiserat sin jaktteknik till att stå blick stilla i luften med kraftigt klippande vingar. Ryttla kallas det. Man brukar se falken ute över vida åkerfält.

Från sin upphöjda position avspanar tornfalken marken efter byten, som nästan uteslutande består av sorkar och möss.

Det ser arbetsamt ut men nu visar forskningen att metoden faktiskt är långt mindre energikrävande än man kunde tro.

Det är två zoologer vid Groningenuniversitetet i Holland, J.J. Videler och S. Daan, som tillsammans med D. Weihs, flygteknisk expert från Haifa i Israel, specialstuderat tornfalken med hjälp av höghastighetsfilmkameror med teleobjektiv.

Oftast har man arbetat med filmhastigheten 100—200 rutor per sekund.



Här mats en uppstoppad tornfalks aerodynamiska egenskaper i ett vindtunnelprov men forskarna har också lyckats trana en levande fågel att flyga i tunneln. Foto YAIR IVAHOF

Effektiv jakt

Tornfalken har hittat en effektiv jaktmetod, det är tydligt. I genomsnitt behöver den bara jaga ett par timmar om dagen för att få ihop tillräckligt med mat. Jämför med t. ex. småfåglar, som bokstavligen ligger i från morgon till kväll.

Men det måste blåsa. Vid vindstilla kan inte falken använda sin teknik utan får vackert sitta kvar på sin viloplats. Principen är nämligen att utnyttja motvinden och arbeta sig uppåtframåt mot den exakt vindens hastighet. Där står man still.

Också vid alltför kraftig blåst måste tornfalken inställa jakten. Då blir tekniken för kraftödande. Idealet är 4—13 meter per sekund.

Glidflyg på stället

Genom att noggrant studera filmerna ruta för ruta kunde forskarna konstatera att tornfalkens huvud under ryttlandet inte förflyttas i sidled eller upp och ner mer än högst 6 mm.

Och det som ser ut som ett oavbrutet vevande med vingarna i högt tempo avbryts faktiskt under korta perioder av vilsam glidflykt på stället, mot vinden.

Varje glid varar visserligen i genomsnitt bara någon eller några tiondels sekunder men tillsammans kan de faktiskt utgöra 10—20 procent av ryttlandetiden.

Det är där energivinsten ligger och tornfalken åstadkommer den genom att elegant och utan att ändra huvudets position i förhållande till marken, förskjuta kroppens tyngdpunkt.

Nu planerar forskarlaget att gå vidare med andra arter med samma flygteknik, bl. a. fiskträrna, fiskgjuse och fjällvråk som också finns i Sverige.

Lennart Lundegårdh

Källa: Journal of experimental Biology 102, 1983.

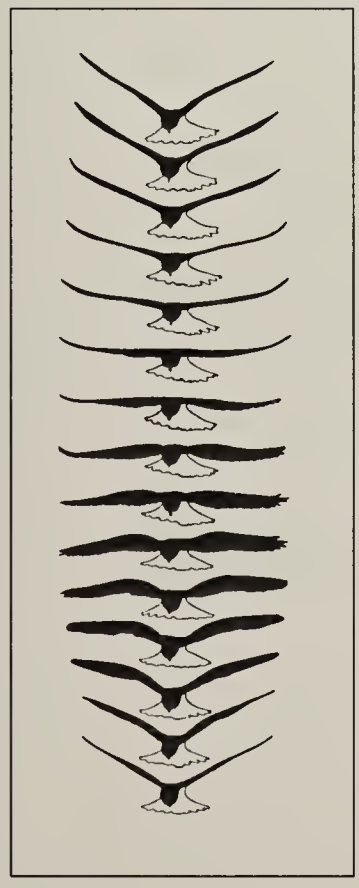
position shown. The newspaper illustration was enlarged 50 percent on an office copying machine. The numbers under the tail of each bird were removed, and the head and wing sections were blackened for a microcapsule copy.

For a buildup display, the bird could be made in three levels:

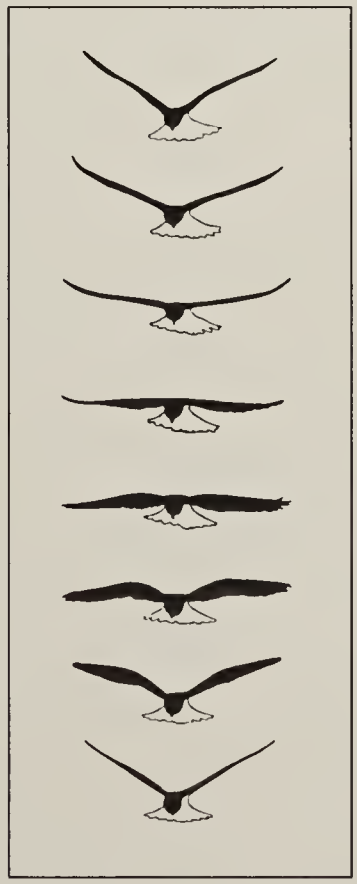
1. A cardboard form of the complete bird.
2. A second cardboard form of wings and head alone that is glued onto the basic complete form.
3. A cardboard form of the head alone that is glued onto the second form.

This process should be repeated until the desired number of birds shows the different movements of the hawk's flight. The birds would then be mounted on a suitable background material.

When this display was tested, two stages were involved. The first display (see A) was tested, and it felt like a human backbone. To remedy this, every other bird was removed from the display—painted over with white paint for a microcapsule paper relief (see B). The result was that, when accompanied by a good verbal or written description, the display was recognized as the flight of a bird.



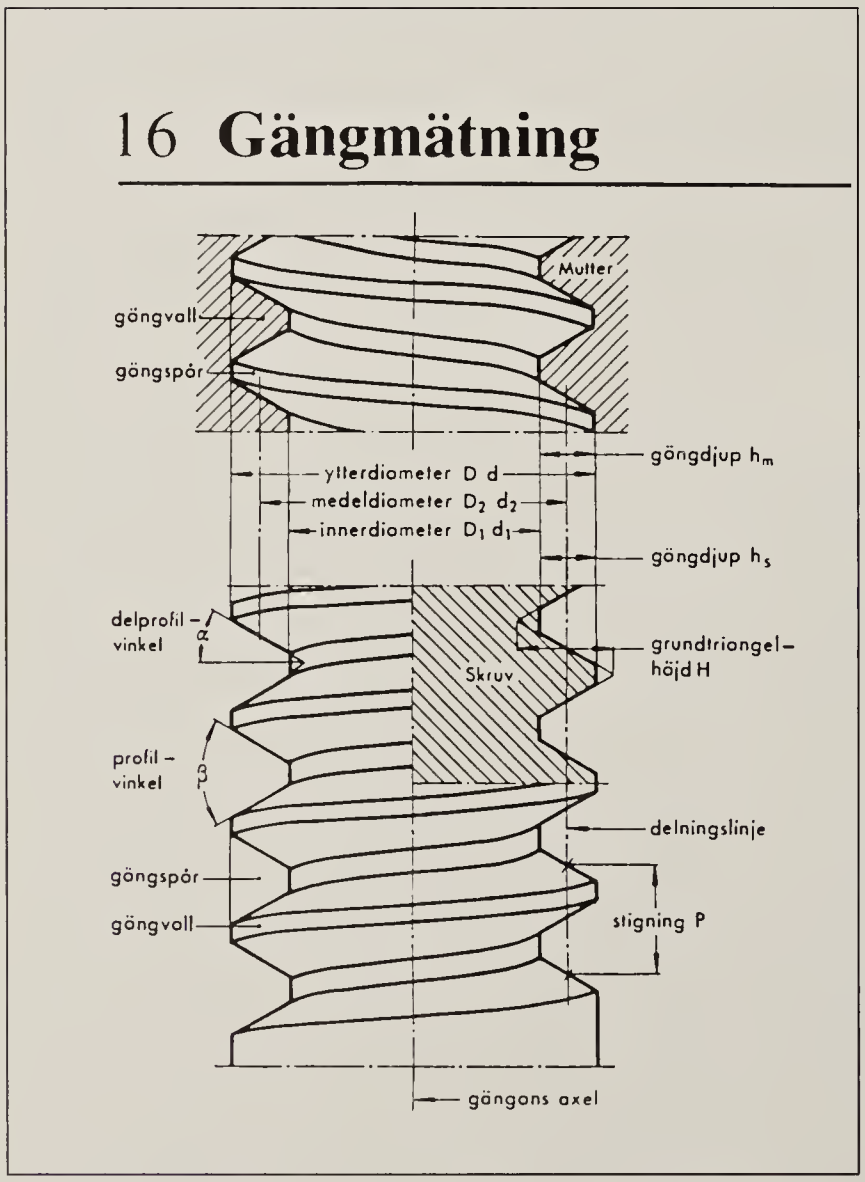
A.



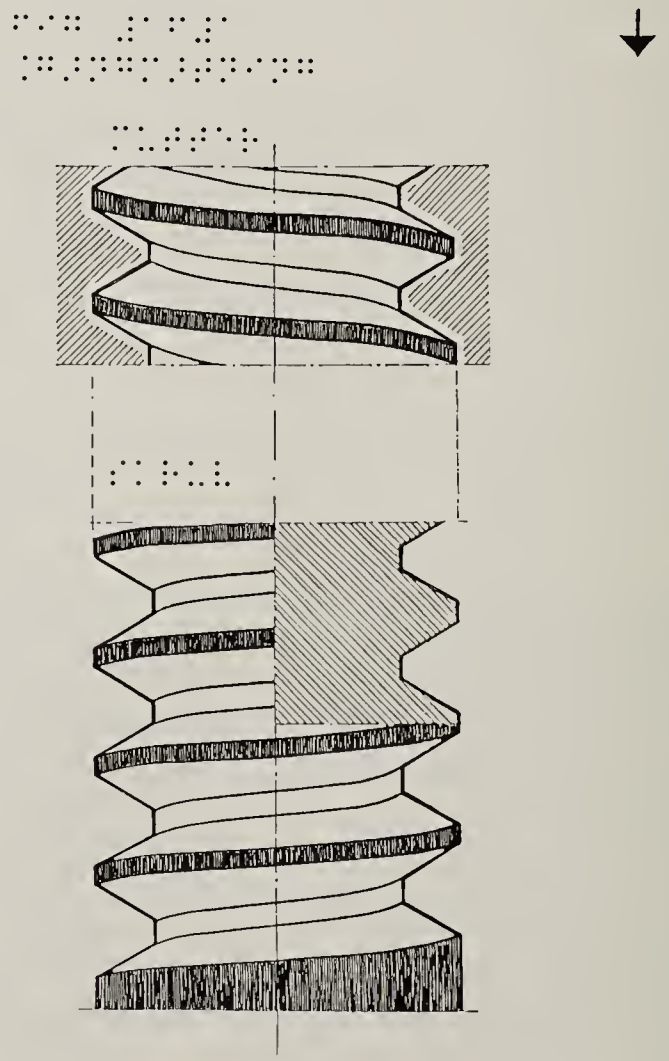
B.

Too Much Information

If you transpose the technical illustration shown here (see A) directly into a relief display, the blind reader will become lost in a clutter of curving lines and arrows and will have a difficult time understanding the actual form of the object portrayed. Therefore, the display corresponding to the illustration was made in two sections. The first section (see B) shows the object without any distracting elements. In the second section of the display (see C), braille symbols and arrows were added to the basic form, and a key was placed on the facing page. The display is still filled with confusing lines and letters, but because the basic shape of the object was established in the first display, the reader can concentrate on the information in the second display instead of wondering what the whole display depicts.

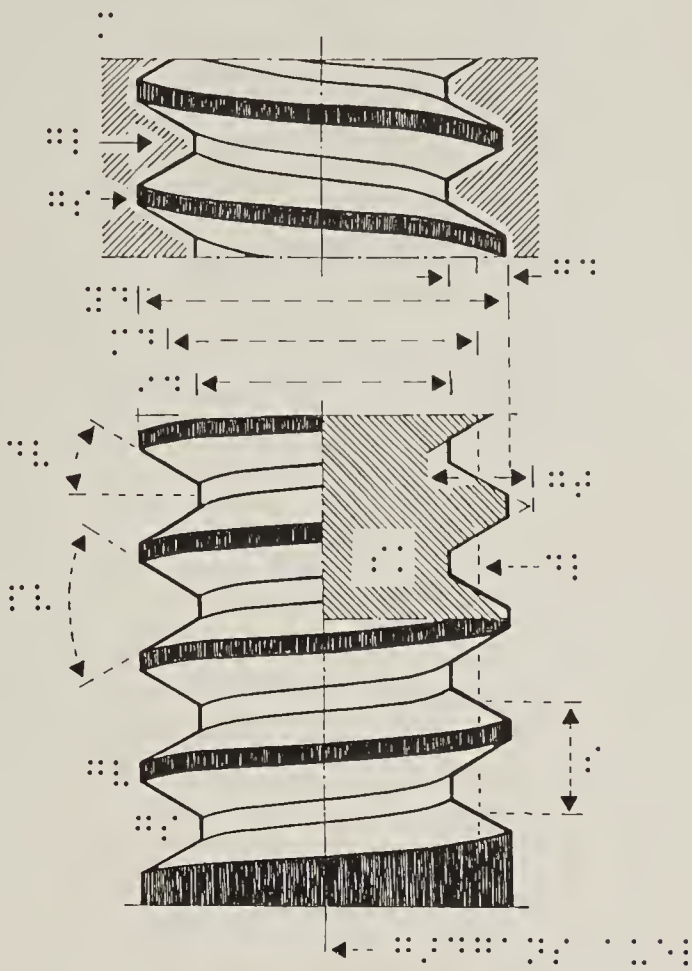


A. A technical illustration showing the measurements of the pitch of the threads of a nut and a bolt.



B. A display of the basic object.

These illustrations were made on microcapsule paper, which involves a one-elevation technique. For best results, a built-up

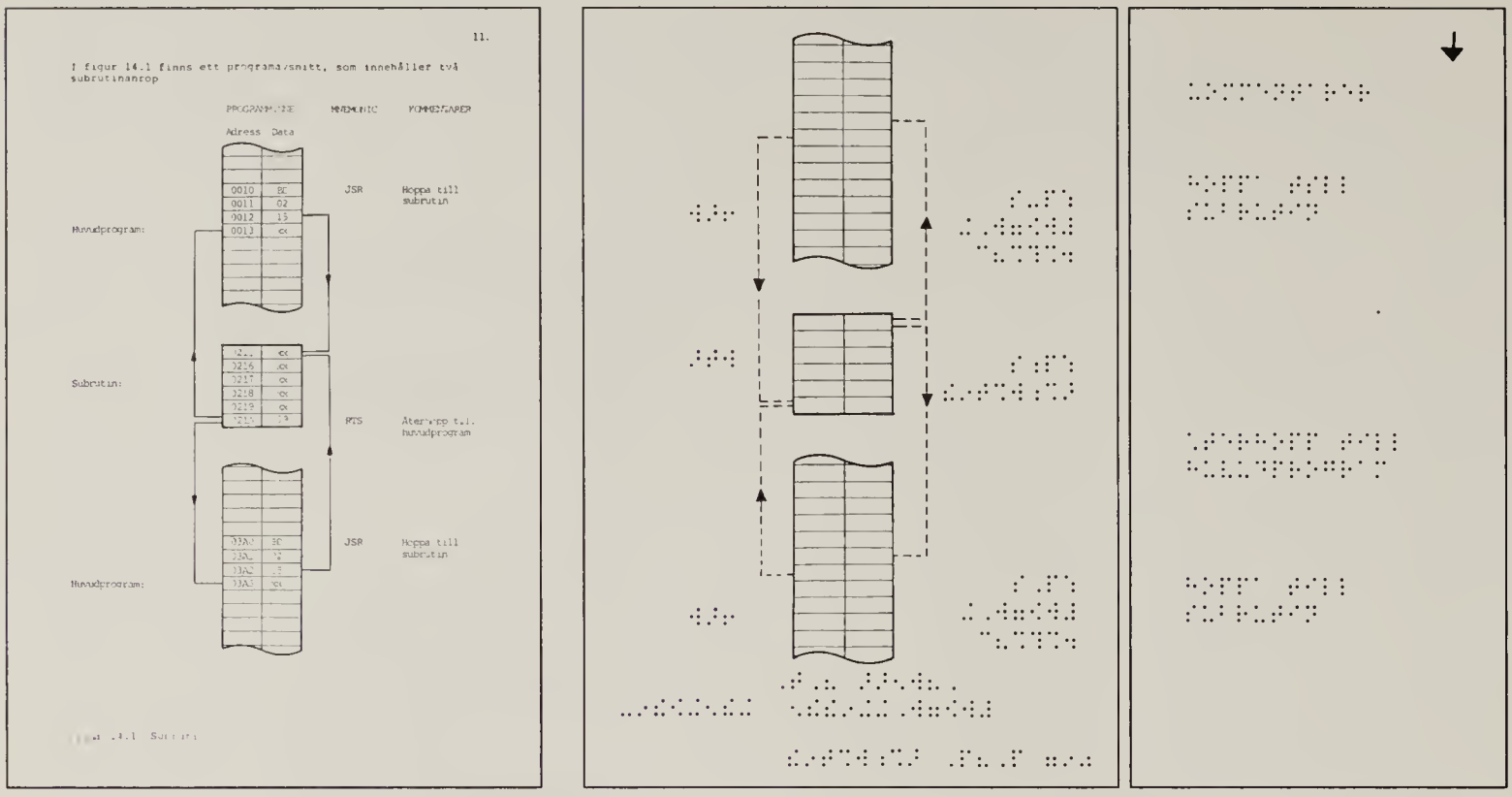


C. The basic form, with arrows and braille symbols added, and the accompanying key.

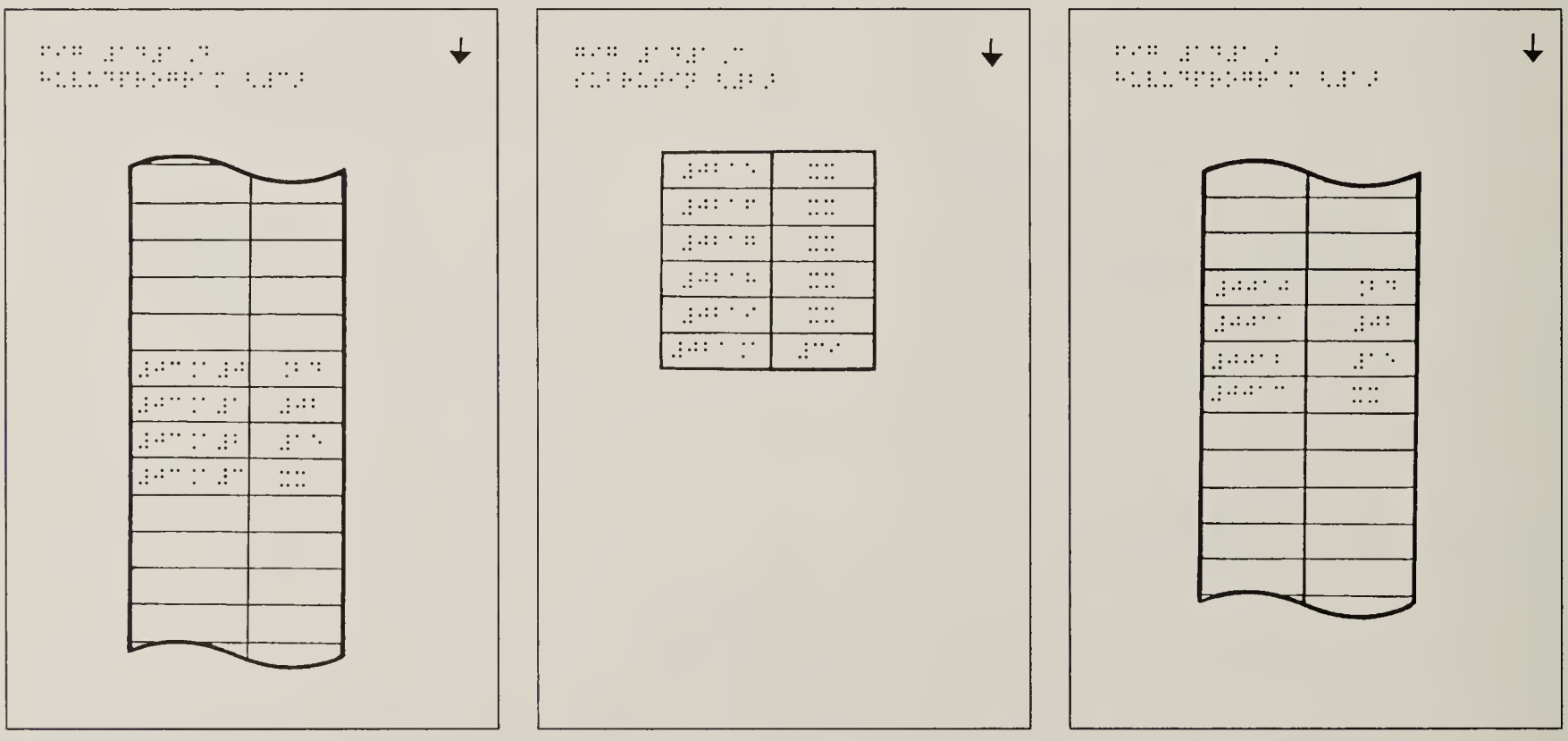
master using several elevations could have been made. This method would allow the fingers to feel the threads of the bolt spiraling down the shaft. Unfortunately, the display was needed immediately, and there was no time to make such a display.

Text as a Determinant of Size

The simple diagram shown on the following page (see A) illustrates how the size of the braille character dictates the size of a relief display. The size of the braille cell and the length of the text in each section made it impossible to put all the information from the textbook illustration on one page of the relief display, so a foldout page was used. The layout on the relief display helps the reader understand the placement and the flow of the different parts. The display was in turn broken down into three displays, each one showing a section of the relief material (see B on following page). The information in the original textbook page was brailled, and the size of the braille dictated the size of the boxes used in the three subsequent displays.



A. A page of a textbook on the technique of using a microcomputer, and a relief display of the textbook page, including a foldout page.

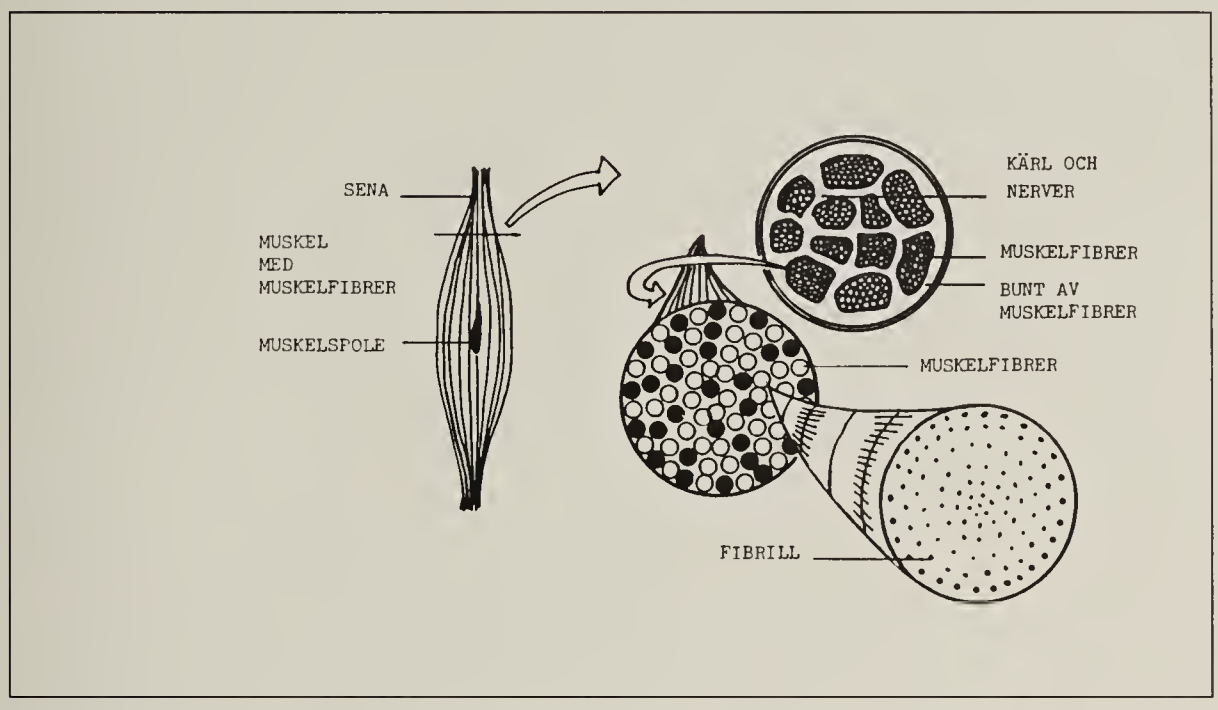


B. Displays showing the three sections of the relief display with brailled boxes.

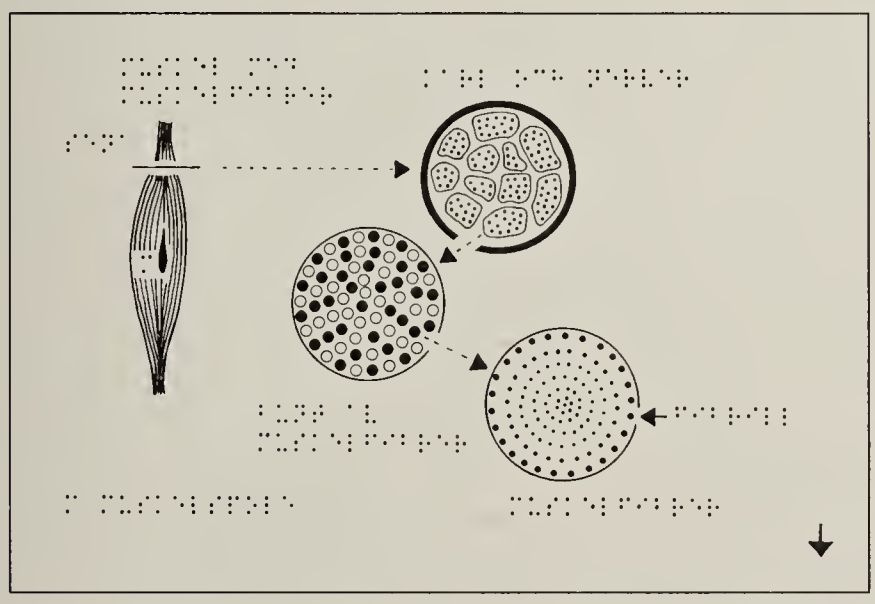
Sequence of Elements

It is important to make a layout that will easily lead the reader through the display, from one element to the next. The original textbook layout shown in the next example describes the construction of a human muscle (see A on the following page). The first relief layout (see B on the following page) exemplifies the unnecessary reconstruction of an inkprint layout. The arrow

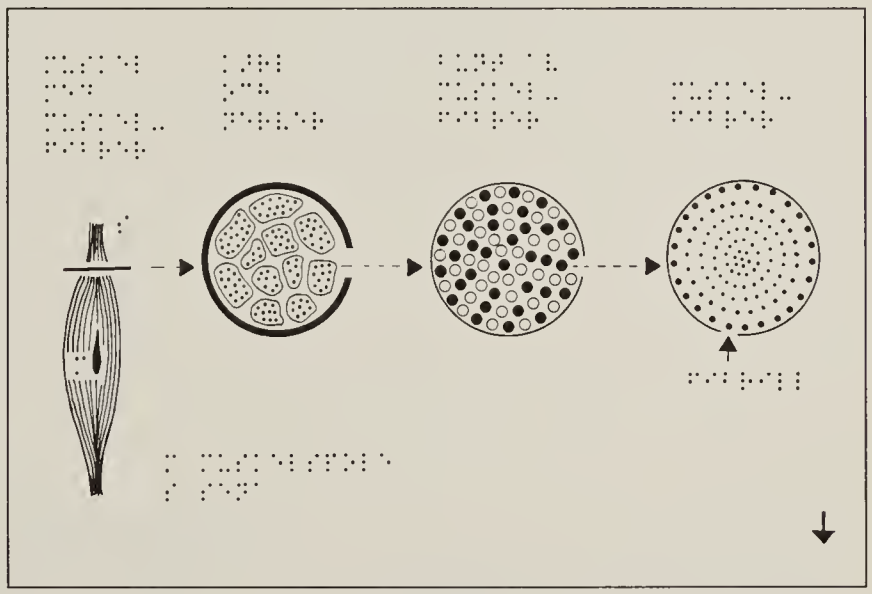
in the lower right-hand corner is a reading-direction arrow. In contrast, the second relief layout (see C) presents the same information in a sequence that is easier for the reader to follow—from a cross section of the muscle to an enlargement of the muscle fiber.



A. The original layout.



B. A display that closely translates the original layout.

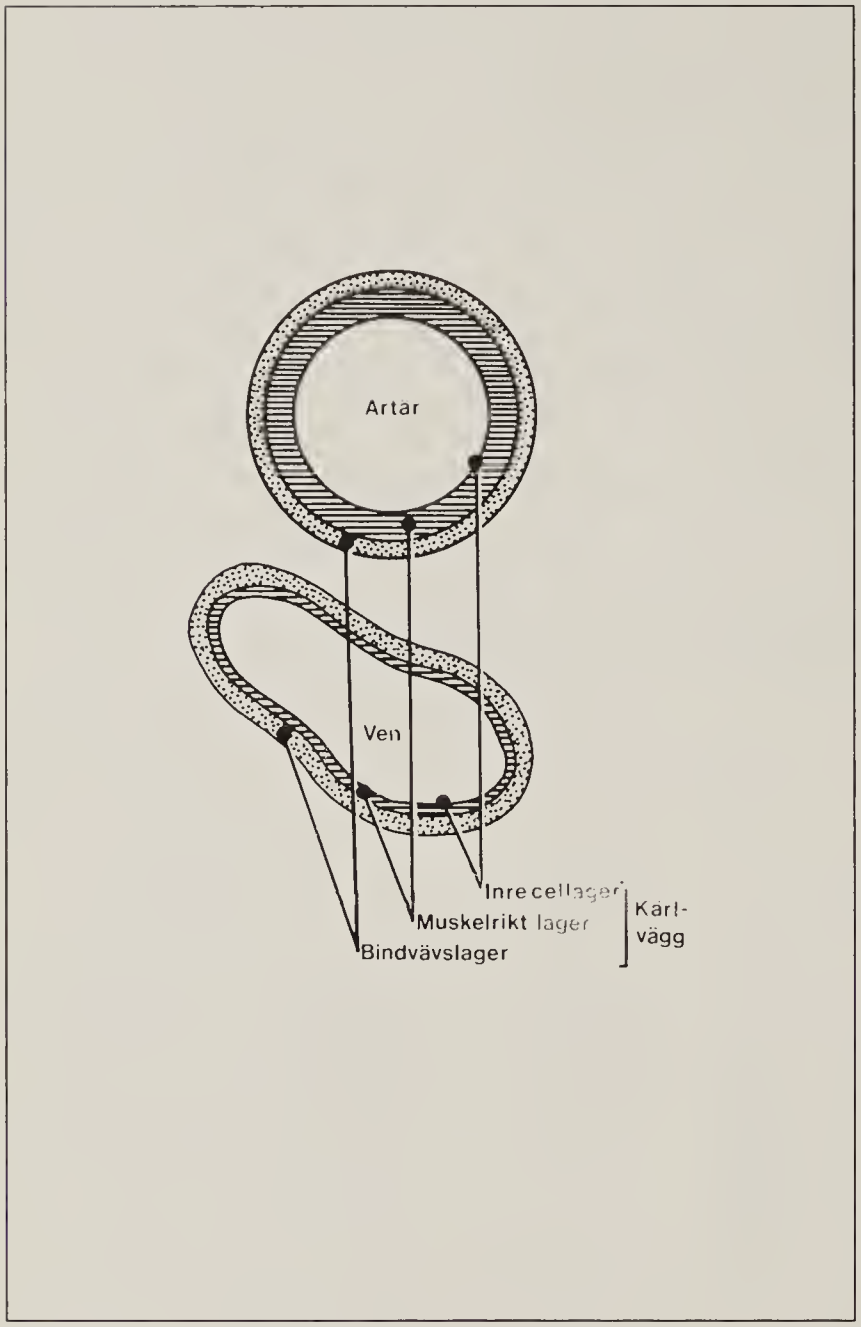


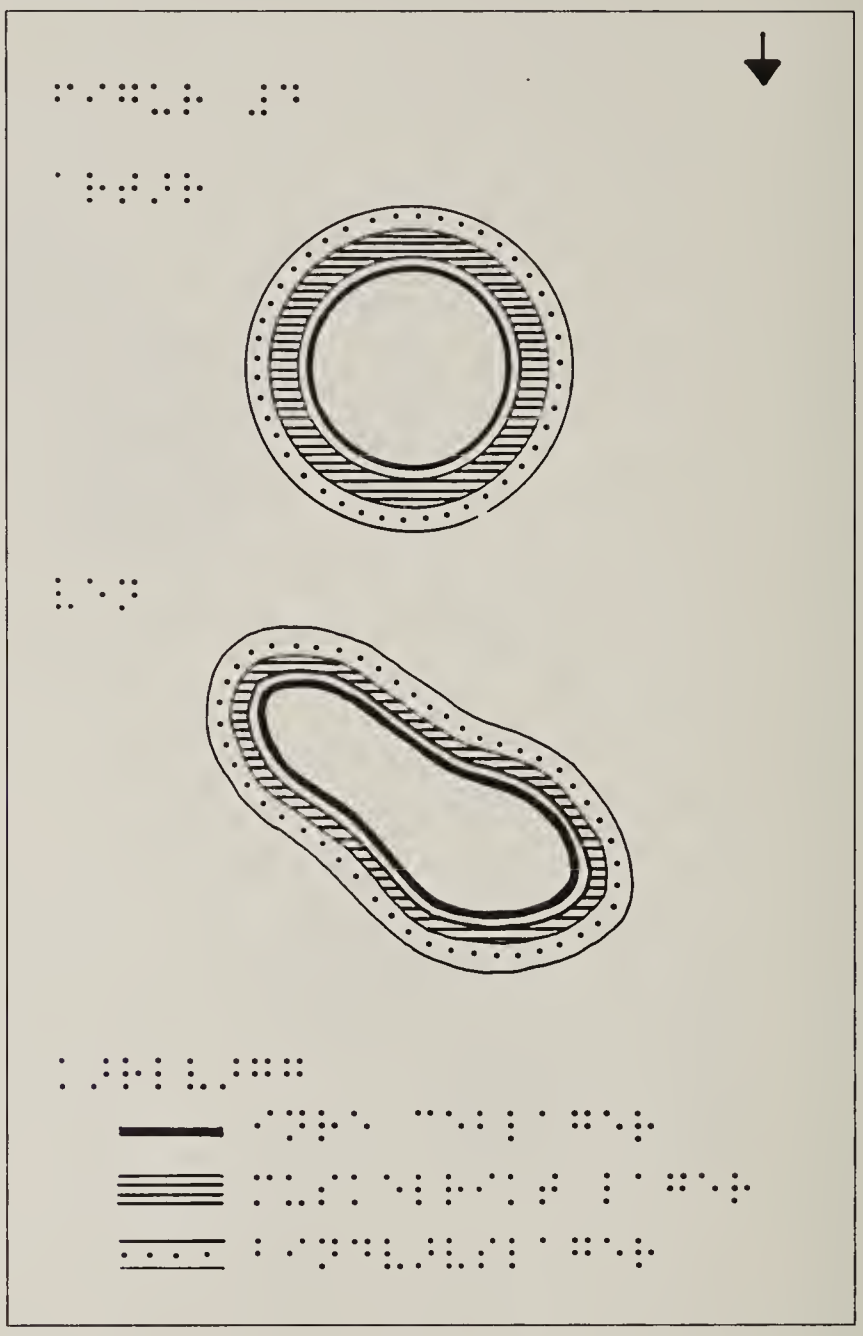
C. A display in which information is presented in a linear, more easily understandable sequence.

Use of a Key

In addition to an orderly sequence of elements, a key will help to eliminate confusion. The cross section of an artery and a vein presented on the next page shows the inner cell layer, the muscle layer, and the layer of connective tissue in the blood vessel wall. The figure is easily understood by sighted students in spite of all the lines connecting the labels to their respective areas. The students can see the complete forms and mentally disregard the lines as not being an integral part of the figure.

Blind students, however, cannot disregard parts of an illustration. Every relief line or form that comes under their fingertips is examined and makes an impression. The blind student simply cannot hop over elements.





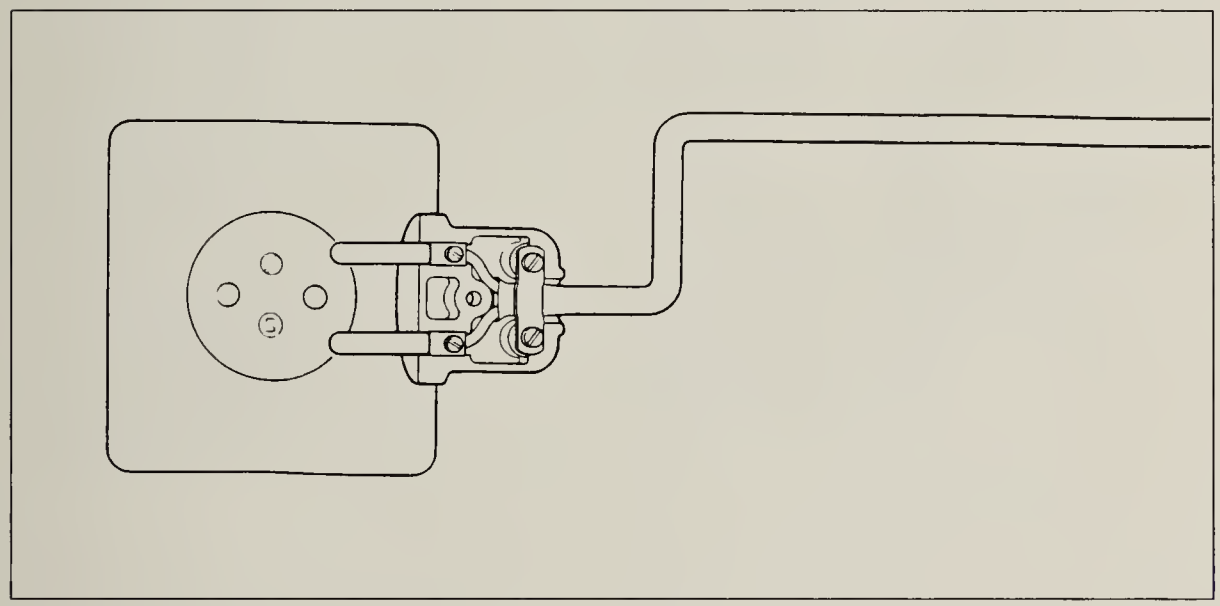
LEFT: A cross-section diagram of an artery and a vein.
RIGHT: A microcapsule paper display, in which a key replaces identifying arrows and labels.

Leaving the cross-cutting lines from the original diagram in a tactile graphic display would tend to make the artery and the vein into a single figure for blind readers. A key is a simple way to eliminate this potential confusion. In the microcapsule paper display shown above, a key has been added. In addition, a white line is used to separate the black line from the striped area, which is necessary for finger orientation.

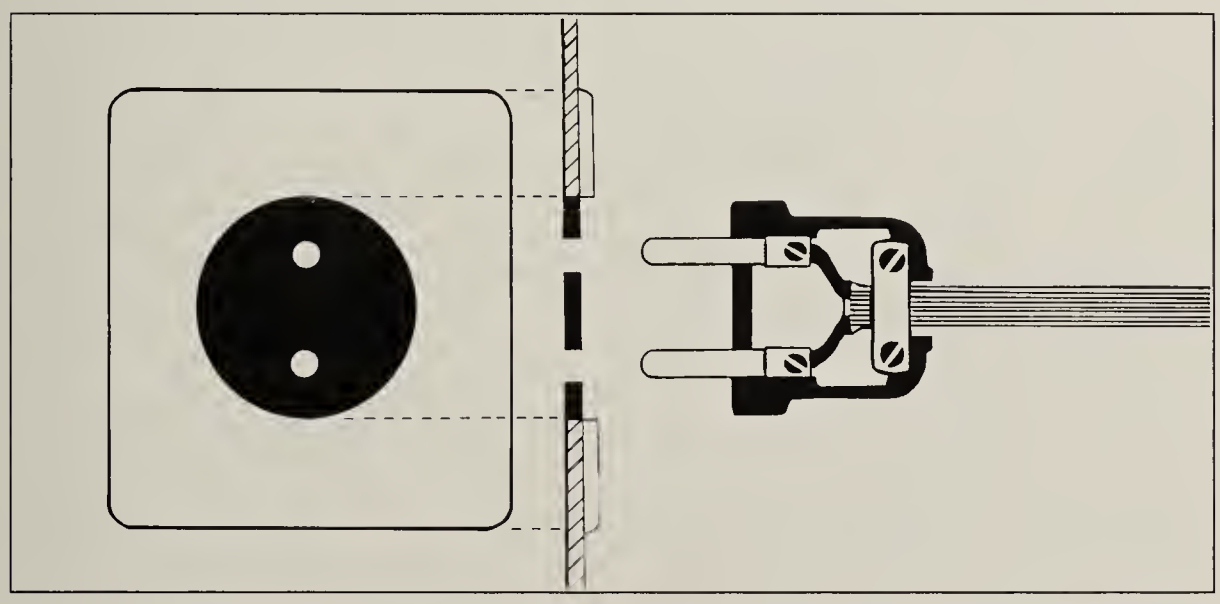
Logical Thinking

It is necessary to think logically when editing an inkprint display. In the textbook illustration of an electric plug and socket shown on the next page, (see A), the plug must be twisted 90° if it is to

fit into the wall socket. The drawing for the relief display made from the textbook illustration (see B) eliminates this problem by indicating that the plug will go directly into the socket. Details such as a screw and a seal of approval symbol have been removed. They could easily have been mistaken for holes for the plug. The electric cord has been straightened out; the curve in the cord in the inkprint illustration did not give additional information to the reader. The change in picture planes that took place was described in the braille text that accompanied the picture.



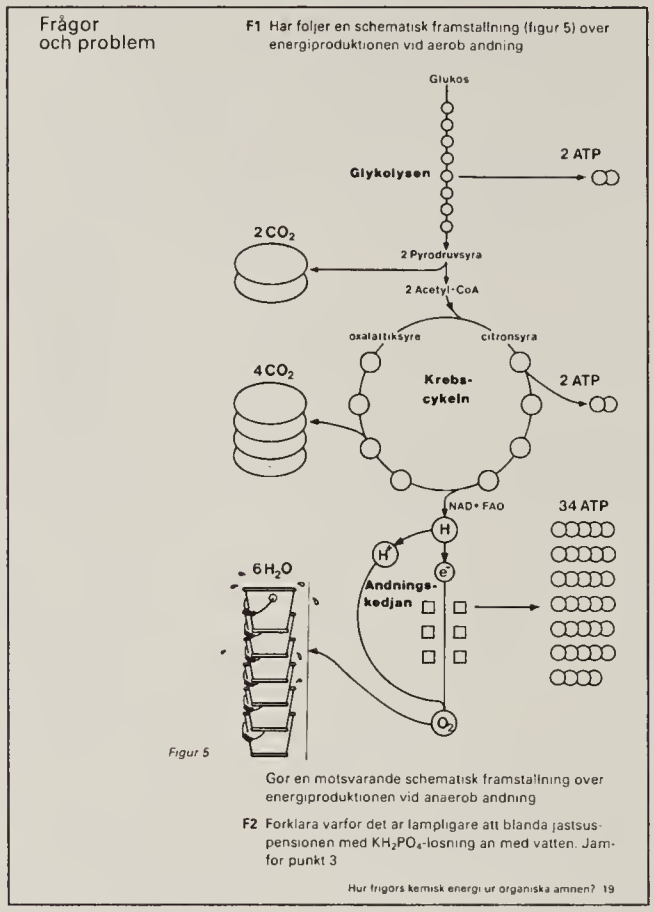
A. A textbook illustration.

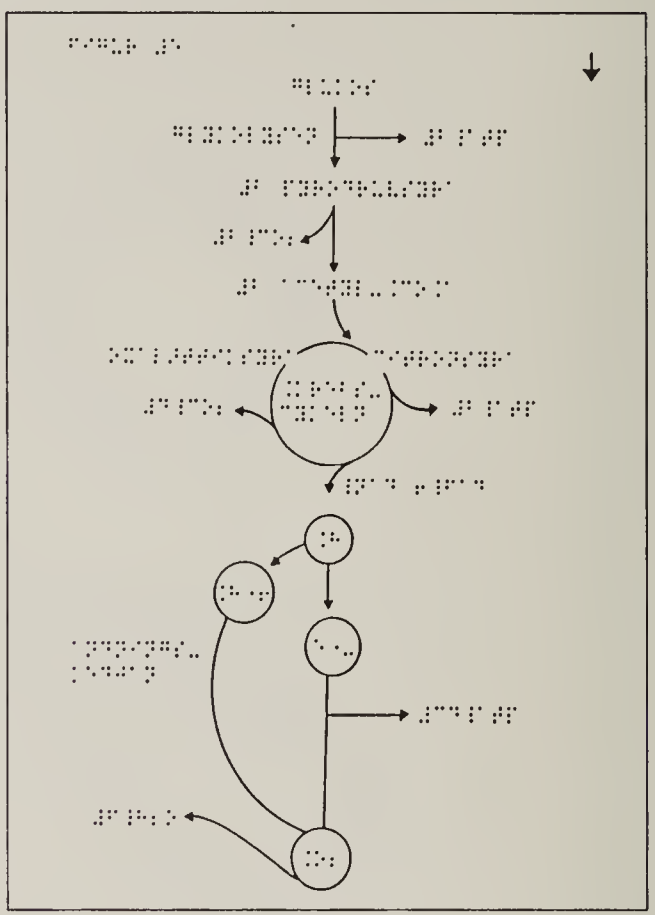


B. A drawing for a relief display that simplifies the original illustration.

The principle of including elements only if they give the reader additional information is also demonstrated by the illustrations on the following page. The textbook illustration shown (see A) depicts the amount of energy produced by an aerobe when it breathes. The pictures included in the illustration repeat the description that was provided in accompanying written text, and by doing so, they may make it easier for

sighted students to understand the subject. However, these same pictures would clutter a diagram for visually impaired readers and make it more confusing, and they should not be included in a relief display (see B). Nevertheless, the layout of the flow of information is definitely necessary.





A. B.

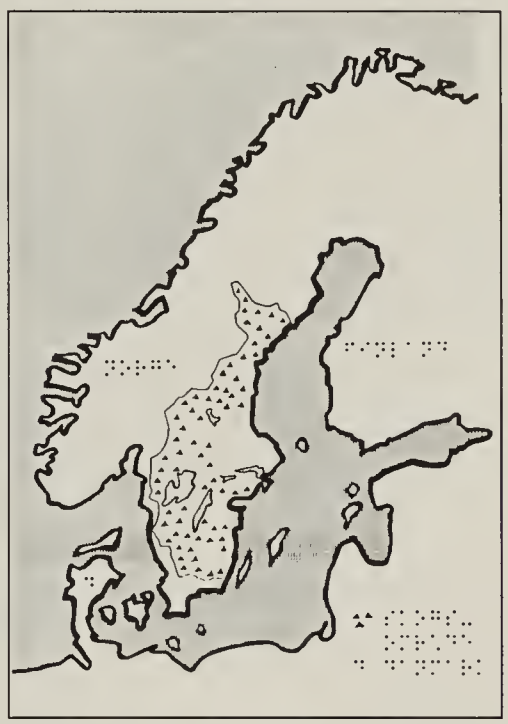
Thought also needs to be given before copying the texture of a printed illustration. The following series of maps demonstrates the different considerations that may dictate decisions.

The textbook map of ancient Sweden shown on the next page (see A) indicates boundaries, wilderness, and the cities of today located on the sites of 12th century villages. In the microcapsule paper map made for visually impaired readers (see B), a larger map of Scandinavia helps the reader to understand the relationship of the country to the surrounding area. The triangle symbol, suggested by trees in the original map, was unfortunately repeated in the relief copy, which led to a cluttered effect. The actual size of the map is 11.5 in. by 8.25 in. (29.2 cm by 21 cm). The triangle symbol is often used to indicate mountains. The way it is used here could therefore be confusing for the reader.

The map is also shown as it appeared in the braille book that was produced (see C). The lined area was easily understood in this one-elevation relief display.

The scale of the maps used in this series is too small to accommodate the quantity of towns shown and their identifying braille symbols. The important point of map D was to show the location of these towns in relation to the rest of the country. Therefore, the map was enlarged, a braille symbol was placed beside each town, and the symbols were identified alphabetically in a key (see E).

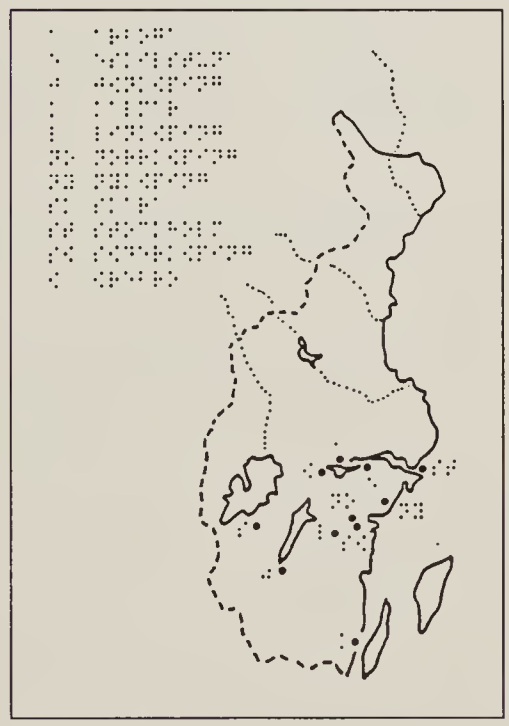
A.



B.

C.

D.



E.

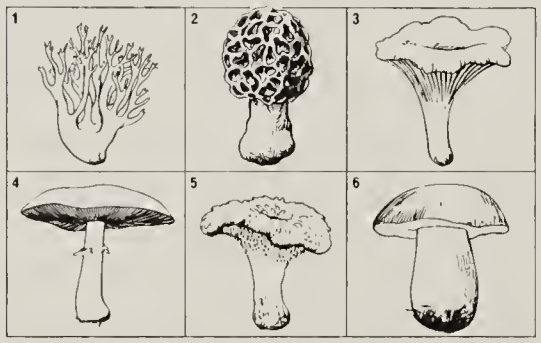
These maps were part of a series showing the changes that took place in Sweden through the centuries. The same water texture, dashed boundary line, and other symbols are presented in a common key at the beginning of the chapter in which the maps appear.

Question-and-Answer Displays

The page shown here (see A) was part of a test compiled for sighted children in the same class level in different schools throughout Sweden. The same test was included in the relief display of materials for visually impaired children in integrated schools (see B). The questions concerned different types of mushrooms. The relief display was made for microcapsule paper but could also be made as a buildup display. Mushroom 1 was simplified and blackened. Mushrooms 3, 4, and 6 were filled in with black to allow the darkened areas to swell when the microcapsule paper was heated. Answer boxes and fill-in lines were eliminated. In the adjoining braille text, the reader was asked to supply the answers to the questions on a separate sheet of braille paper. It is much easier for the reader to answer questions in this manner, since it is difficult to try and fit the braille text into a designated area when using a braillewriter.

I svampskogen

1. VILKA ÄR SVAMPARNA?



Svar 1

champinjon	
kantarell	
karljohanssvamp	
murkla	
taggsvamp	

2. VILKET SVAR ÄR RÄTT?

1. Hur ser skivorna ut hos lomsk flugsvamp?
   A. vita
   B. ljusbruna
   C. nästan svarta
2. Var bildas sporerna hos buksvampar?
   A. på utsidan
   B. inuti svampen
   C. där svampen sitter fast
3. Hur har järksoppen fått sitt namn?
   A. den växer nära lärkbon
   B. den sprids av lärkor
   C. den växer nära lärkträd

Svar 2

1	
2	
3	

3. SVAMPARNAS SPORER

1. Vilka fakta gäller svampsporer?
   A. kan flyga långt med vinden
   B. sitter runt foten
   C. är förökningskroppar
   D. är motståndskraftiga mot torka
   E. är alltid vita
   F. kan gro

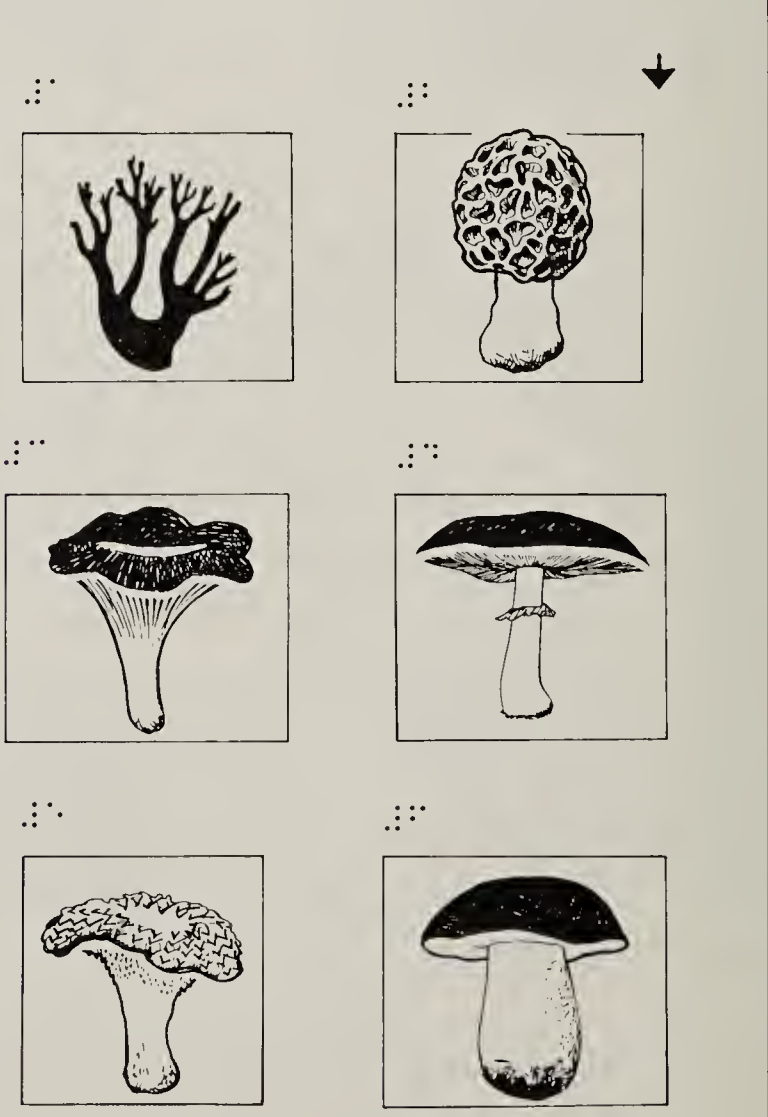
Svar 3

1	

Namn: .....

1

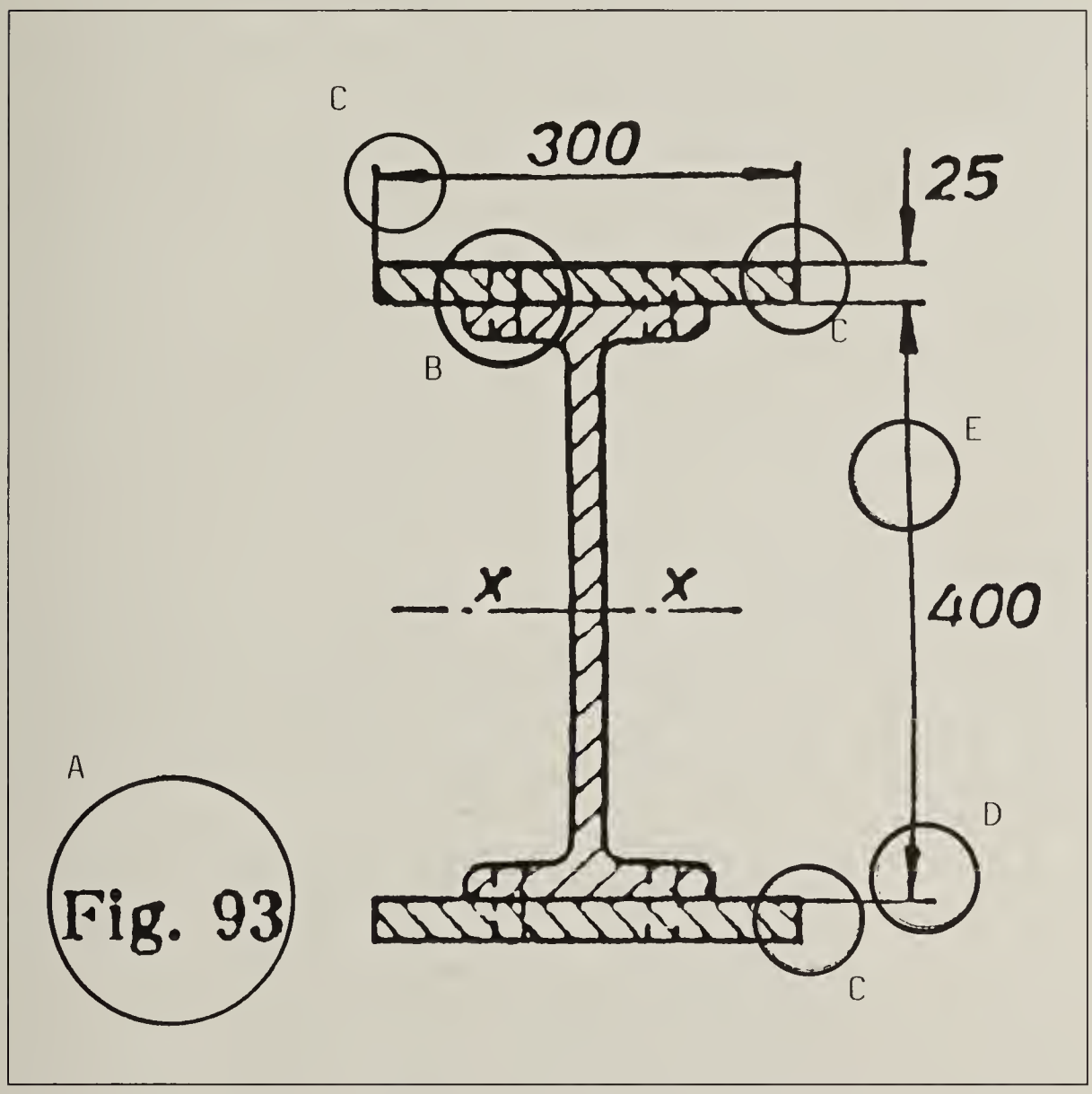
A. The inkprint test.

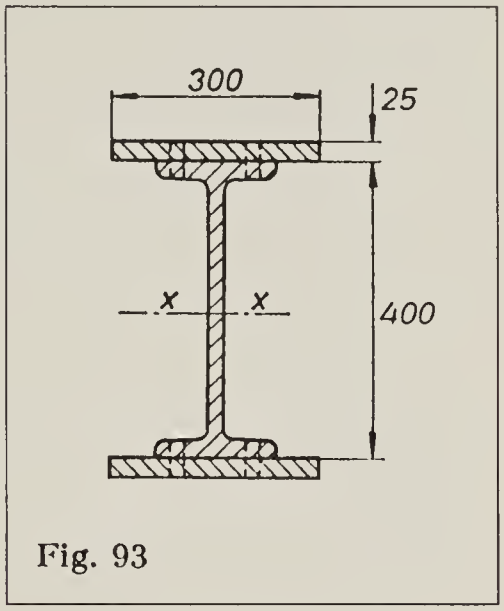


B. The corresponding relief display, which was accompanied by a separate braille answer sheet.

From Textbook to Braille Book

When converting a textbook illustration into a form appropriate for a braille book, enlarge the textbook figure to a size that can be understood by fingers—that is, to a size that can accommodate the necessary braille numbers and letters. The textbook figure shown here represents an I-beam, strengthened at each flange by steel. The actual size of the figure made for a braille book was 5.5 in. (14 cm).



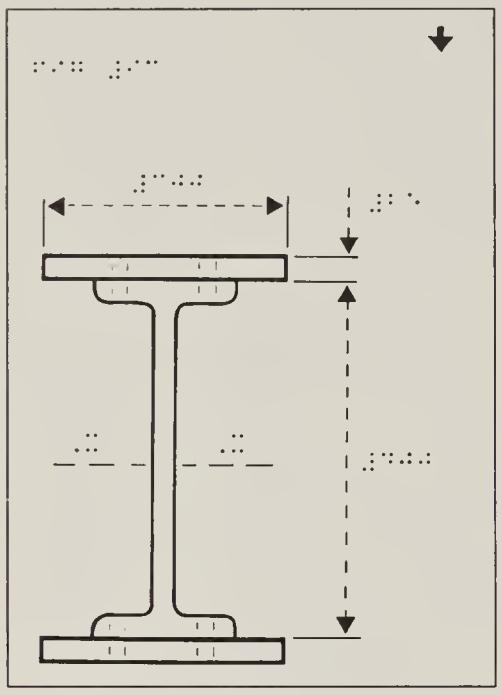


The actual size of the figure in the textbook.

An enlargement of the textbook figure.

The problem that students were supposed to solve asked how many rivets of a certain size were necessary to fasten the beam in place. To make the one-elevation, microcapsule paper display of the figure shown here, the striped pattern was removed from the beam. It is impossible to feel the placement of rivets through an elevated surface texture. If the texture on the beam had been interrupted to allow a white area around the lines to indicate the placement of the rivets, the reader might have gotten the impression that the I-beam and the attached steel were made up of many separate pieces.

Other alterations made to the original illustration are as follows (the letters cited here refer to the circled areas on the enlarged illustration):



The microcapsule paper display of the figure.

- The figure number was moved above and to the left of the figure, establishing the reader's first contact with the figure and eliminating the need to scan the figure to find the example number (A).
- The placement of the rivets was indicated (B).
- All lines that were not part of the I-beam were detached from the actual shape of the beam (C).
- All arrowheads were widened to 45° for easy recognition (D).
- In order to ensure that lines connecting arrowheads would not be mistaken for part of the beam form, they were changed to dashed lines (E).
- A reading-direction arrow was added in the upper right-hand corner. When this arrow points toward the reader, the display is in its proper position to be read.

One Way to Edit a Map

The map shown here of Uppland, a province in Sweden, was used in beginning geography classes for sighted students. It is presented to show that even a simple map must be edited if it is to be used as the basis for a relief display. This map was

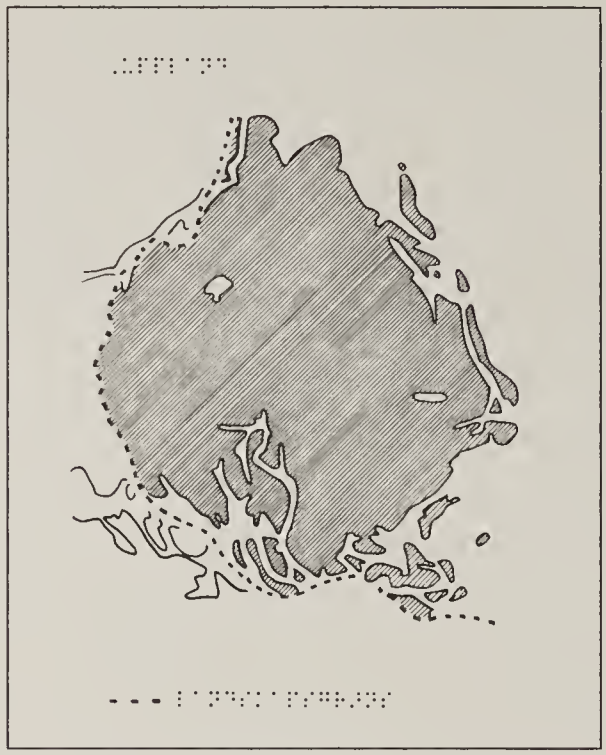
printed in three colors—green, blue, and black. The green land made it easier for the sighted student to recognize the province in its entirety.

This map can be made into a relief master paper buildup with several elevations or a pen-and-ink original for microcapsule paper copies of one elevation. Both of these methods can be mass-produced. The following comments are equally valid for both methods. A microcapsule paper example is shown here.

When editing a picture or map, you must first of all decide the purpose of the material and what is most important to depict. In this map, the purpose is to present the area of Uppland as a complete form. The information on the map is important only if the classroom discussion deals with the province in depth.

For the master, make an outline drawing of the area, simplifying the outline, when necessary, for easy recognition. The reader should not be caught in confusing areas. When working with microcapsule paper, remove all inkprint names, numbers, and compass directions, and, if necessary, change the scale to the one you will be using. In the following maps that are shown here, which are part of a step-by-step series, the placement of the name of the province, Uppland, also indicates the direction north (see "North," Chapter 6). The scale was written into the text that accompanies this series of maps. However, to be correct, it should have been included on each one of these maps!

This map, made for beginning readers, shows the location of the province of Uppland in Sweden. It is not necessary to include this map or to use such an extensive step-by-step map series for more advanced readers. However, it is always useful to have some source material to which the reader can relate.



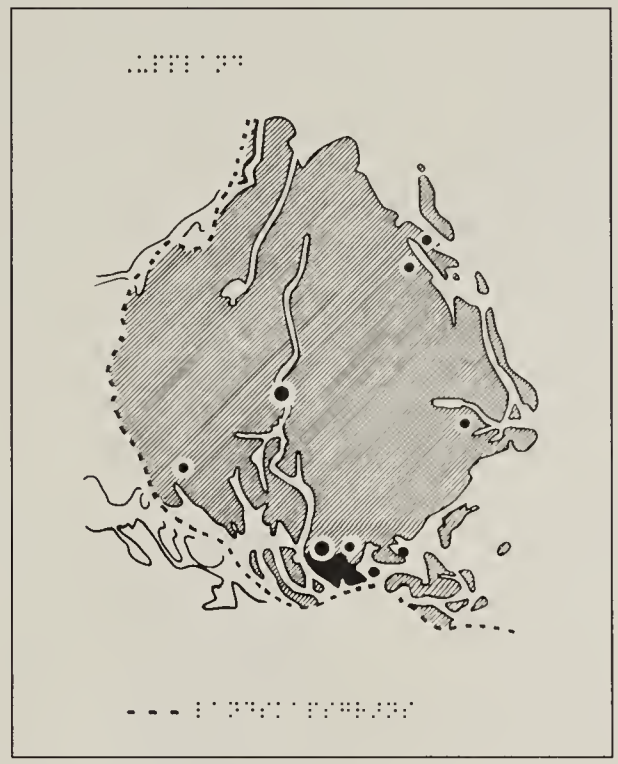
The complete form of the province is emphasized in the next map by using only one texture in the display. The shape of the province would not have been as dominant if the water area had also been given a texture. By reducing the size of some islands and moving others farther away from the coast, the space between the islands was enlarged to make them more readable. A heavy dashed line was added to show the common boundary of adjoining provinces.

Rivers were then added to the basic form, as shown here. They were widened to allow readers' fingers to find and feel them in the textured area.

Cities were added next; the white area around each dot makes it easier for the reader to feel the dot. The line around the coast stops to allow a white area to circle a coastal-city dot. The outline of a river is stopped for the same reason. The upper right and lower left dots were moved inland to allow for a larger white area around them. The city on an island, lower center, is without an island. There was no room for both of them, and the city was more important.

On a master display of several elevations, the cities would be mounted on top of the basic land form; they would not have to be moved away from the coastline, since they would be on another elevation. It might, however, be necessary to enlarge distances between symbols, a minimum of 1/8 in. (3 mm) to facilitate recognition.

In the next map, highways were added, prominently, with no black borderlines on either side of the stripes. This differentiated them from the rivers. On a master display, the highways would also be single-line, wide strips, more elevated than rivers but not as elevated as the city symbols. This map alone would be sufficient for more experienced readers of one-elevation maps. A key and scale for the map should accompany this display if it is to be used by itself.



The various elevations of a master display might make a step-by-step series of plastic or built-up maps unnecessary. The editing you do is based on your reader's ability to understand the relief material—and your ability to recognize his or her capacity for understanding such a map.

Thinking Beyond the Textbook

There are times when it seems impossible to transpose a textbook illustration into an understandable relief display. This is a frustrating situation for the student, the teacher, and the producer of the display. The student, most often in integrated classes with sighted pupils, feels left out when the class discusses the textbook's printed maps (see A and J in the following pages). The teacher, who may have worked with sighted students for most of his or her teaching experience, feels hampered by not having sufficient material to use with the blind student.

In the microcapsule display shown on the next page (see B), the producer tried to create understandable relief material corresponding to the printed map shown of the inland ice in the area around the Baltic Sea. Note that if the ice cover is to

be correctly shown in the braille version, the complete area inside the dashed line should be striped. Yet when such a map was made for blind students, they became disoriented. It was necessary to show the Baltic Sea as an unstriped area to help the students gain their geographic bearings. The microcapsule version (B) here is therefore a compromise, and a confusing one at that. The teacher asked the producer to try again. An ice-age kit became the solution.

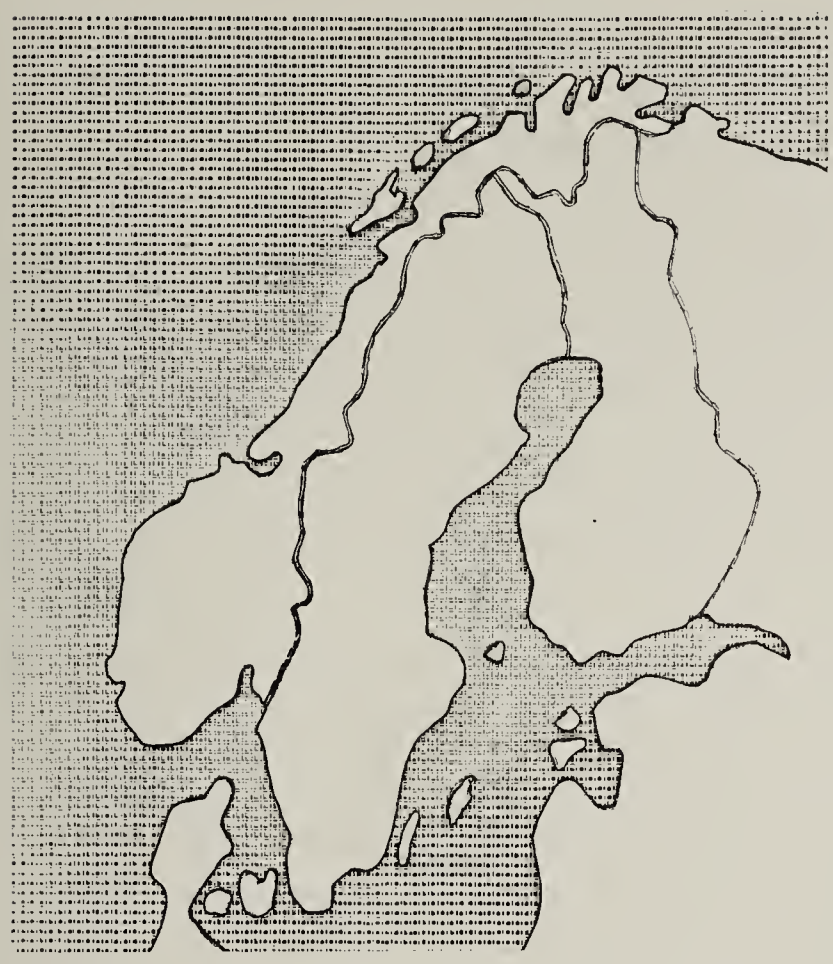
A. A printed map showing the extent of the inland ice that covered the countries around the Baltic Sea 10,000 years ago.

B. A microcapsule paper version of map A.

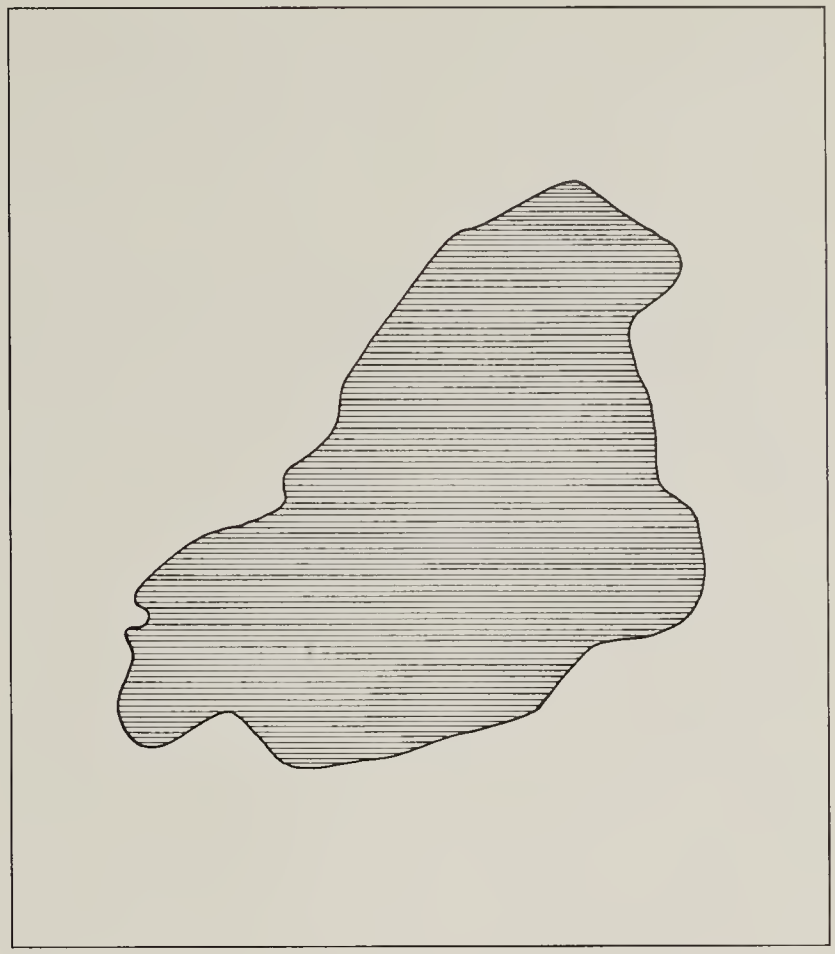
A main component of the kit is the simple map of Scandinavia shown on the next page (see C), in which shapes are cut out of cardboard and mounted on embroidery canvas. The national boundaries are of knotted string. Plastic copies can be made from this master.

The shape of the inland ice cover is printed on microcapsule paper in the illustration shown next (see D). The teacher or student should cut out this form. With help, the student can place it on the simple map (C) by using tape or pins (see E).

The expense of precutting the outline material in the kit

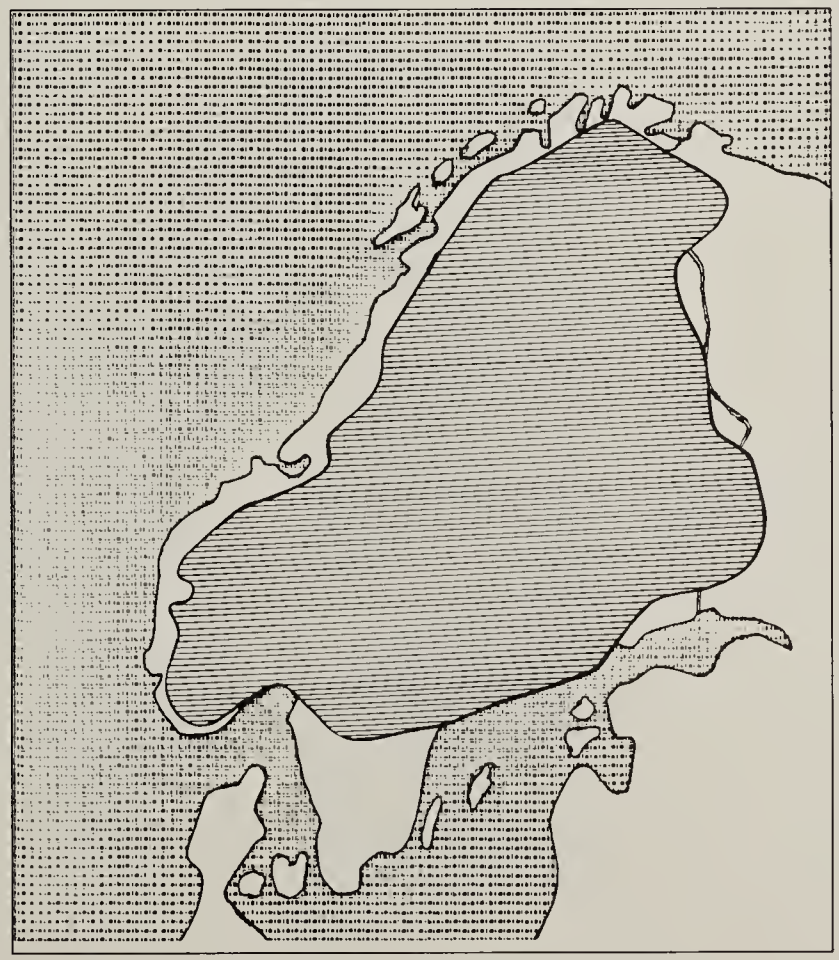


C. A simple map of Scandinavia, in which shapes of cardboard are mounted on embroidery canvas.



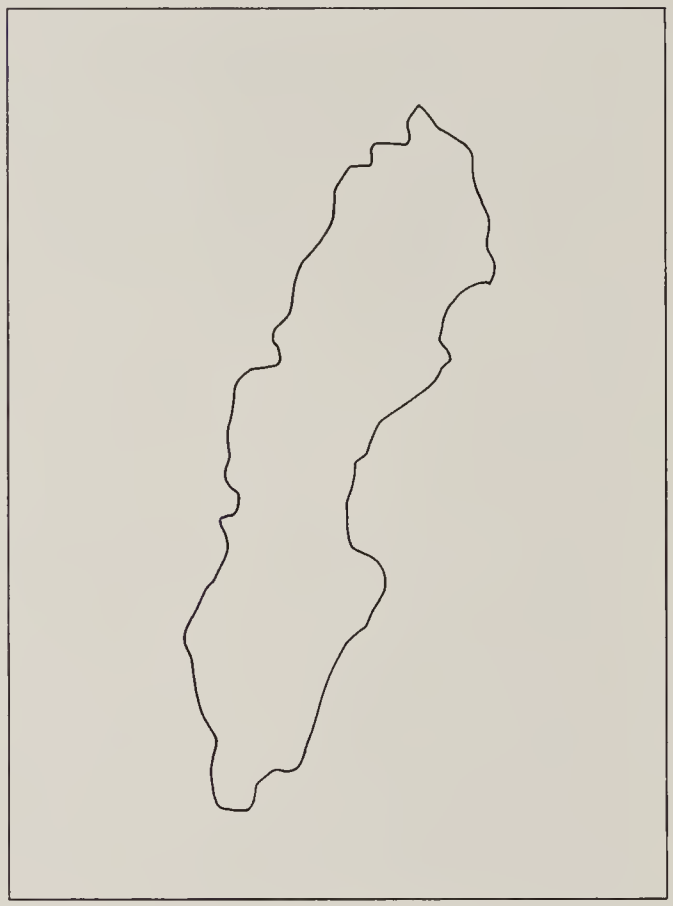
D. A microcapsule paper cutout of the inland ice cover that extended over Scandinavia.

would prohibit it from being sold at a reasonable price. Therefore, the teacher's cooperation in cutting out the materials is necessary. Printed directions and a short history, *From the Ice Age to Today,* are part of the kit.



E. The shape of the inland ice cover placed on the simple map of Scandinavia.

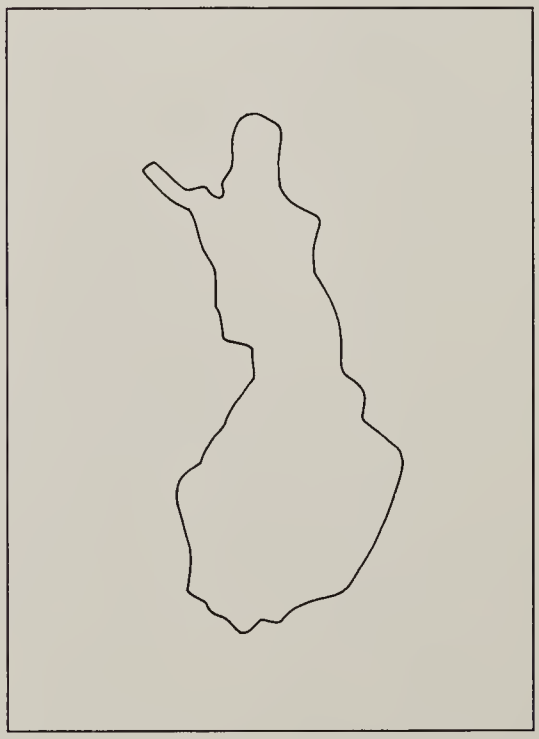
Included in the kit are Sweden, Norway, Denmark, and Finland in outline (see F, G, H, and I, respectively). They are printed on thin cardboard sheets, each of a different color. Color makes this material more appealing to students with low vision or unimpaired sight. When cut out, these shapes fit into the areas on the simple map of Scandinavia (see C) or on plastic copies made from that master.



F. Sweden.

G. Norway.

H. Denmark.



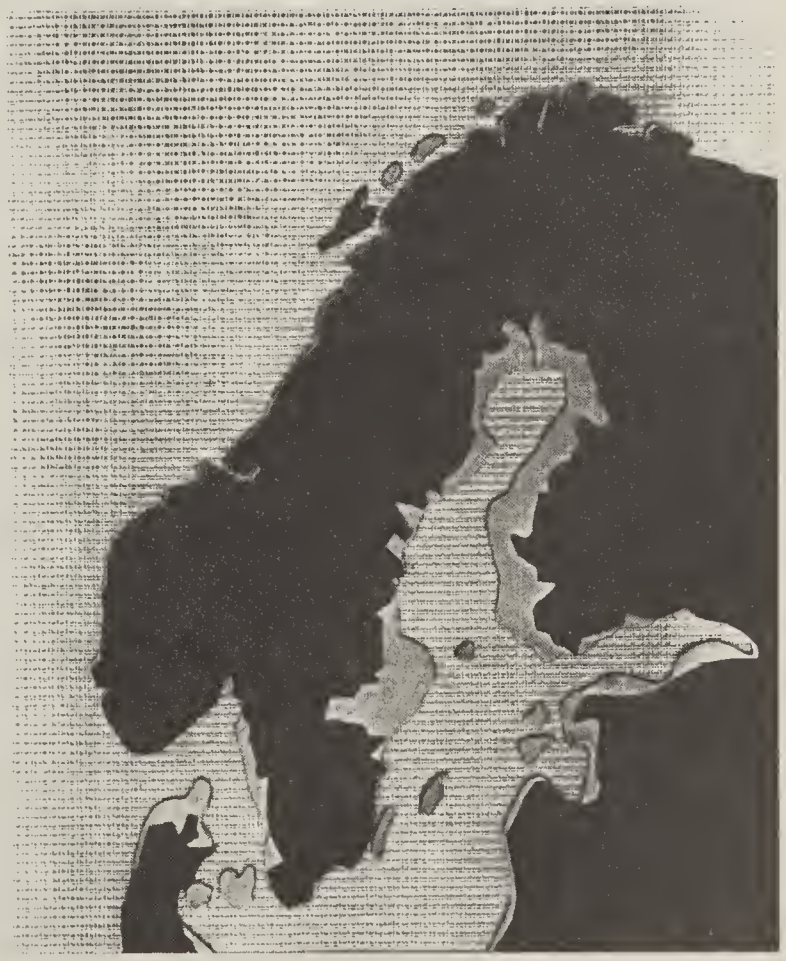
I. Finland.

These shapes are useful for recognizing a country by its shape, learning the location of each country on the simple map of Scandinavia, and comparing the sizes of the countries in Scandinavia. They are also useful as maps in themselves (cities, in the form of cutout circles and squares, can be added to each country as the need arises). In addition, students can make stencils by drawing around each shape on their raised-line drawing boards, adding cities, rivers, and so on, as desired.

The next map shown here (see J) illustrates Scandinavia 6,000 years later. The inland ice has melted, and land now consists of the area shown in silhouette in map K. The outline for this silhouette is printed on thin, colored cardboard. It can be cut out and placed on top of C, the simple map of Scandinavia (see L), to compare the amount of land existing 6,000 years ago with the land area that exists today.

J.

K.



L.

Editing material for relief displays can be especially complicated when you are not sure about the use or importance of the material. At such a time, personal contact with the teachers who will use your material is invaluable. There may be particular points in a picture or map that should be emphasized to fit the teaching program—points not obvious to you. Or a desired picture may be best described in words or with objects—its presence may therefore be unnecessary. Discussions frequently clarify these issues.

Ask the teachers with whom you work to look through the books that they want transcribed into braille and to mark the illustrations that should be produced, using this order of preference: (1) a necessary illustration, and (2) a desired illustration, if there is time to make it. It is often impossible to produce all the illustrations in a book.

Relief displays can be used individually, bound into textbooks, or placed in loose-leaf picture or map binders, depending on the nature of the material and the desires of the teachers and students. If this material is to be included in some type of book, be sure that you leave enough space on the left-hand side of the display page to accommodate the necessary binding. Information about unusual symbols, techniques, and unfamiliar layouts should be given to the reader at the beginning of a book, on a separate sheet accompanying a series of loose displays, or in a map key.

Try to maintain contact with the teacher and the students after you deliver relief material. Their reactions can be a great help in your work on future productions. A questionnaire may be useful when you cannot talk to them personally (see Chapter 10 for an example).

TRANSFERRING A SKETCH

There are several simple ways to transfer a sketch to background material.

- Place tracing paper or drafting paper on top of the printed picture or map. The printed display will show through the semitransparent paper, and the image can easily be traced with a pencil.
- To trace for a negative image (when making embossed

displays on metal foil or braillewriter paper), use either of these procedures:

1. After tracing the image with a pencil using the method just described, reverse the semitransparent paper and place it on top of the background material. Emboss directly through the paper onto the background material. Reverse the background material for further work on the display.
2. Place the printed picture or map on top of a sheet of braille paper or foil. Place a sheet of carbon paper *under* the braille paper or foil, with the carbon side against the braille paper or foil. Draw directly on the printed material. The image will be imprinted on the back of the paper or foil that has been placed under the printed display. Reverse the braille paper or foil and emboss it with embossing tools, a sewing machine, or another medium. When the paper or foil is reversed once more, the embossed image will appear in its correct position.

- To trace for a positive image (used for buildup displays or for separate parts of a display that are to be cut out with a knife or scissors), use either of these procedures:
  1. To prepare a picture, map, or diagram for transfer to another surface, trace the image on tracing or drafting paper. Then, reverse the tracing. Select a soft, black lead pencil. Do not use the pencil in a perpendicular position with the pointed lead tip against the paper; hold the shaft of the pencil almost parallel with the paper so that the lead makes a wide black path. Cover with a wide swath of pencil lead only those lines and areas that are to be retraced onto the background material. Reverse the semitransparent paper once more, and place it on top of the background material. Redraw the lines. The image will be imprinted on the material underneath.
  2. To use commercial carbon paper, place the carbon paper, carbon side down, between the original sketch and the material to which it is to be transferred. Redraw the sketch, using the point of a hard lead pencil. The lines and areas will be transferred to the new material.
- To transfer an image directly from a nontransparent original,

use a light table or hold the original, back side up against a window pane (the image will be visible through the back side of the paper if the light is strong enough). Cover the lines and areas to be transferred with the flat side of a lead pencil. Reverse the original display and place it on the background material. Redraw the lines. The image will be imprinted on the material underneath.

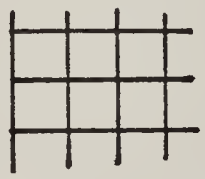
- The pantograph and several of the projectors mentioned in the following section are also useful for transferring a sketch without changing its size. An office copying machine can be used if the material to which you are transferring the image is not too thick to pass over the rollers that advance the paper in the machine.

ENLARGEMENTS AND REDUCTIONS

Graphic material often needs to be enlarged or reduced in size before further work can be done on it. The following methods and machines are for that purpose.

Grids

A grid consists of a network of evenly spaced horizontal and vertical lines. Using this kind of system does not require any extra equipment.



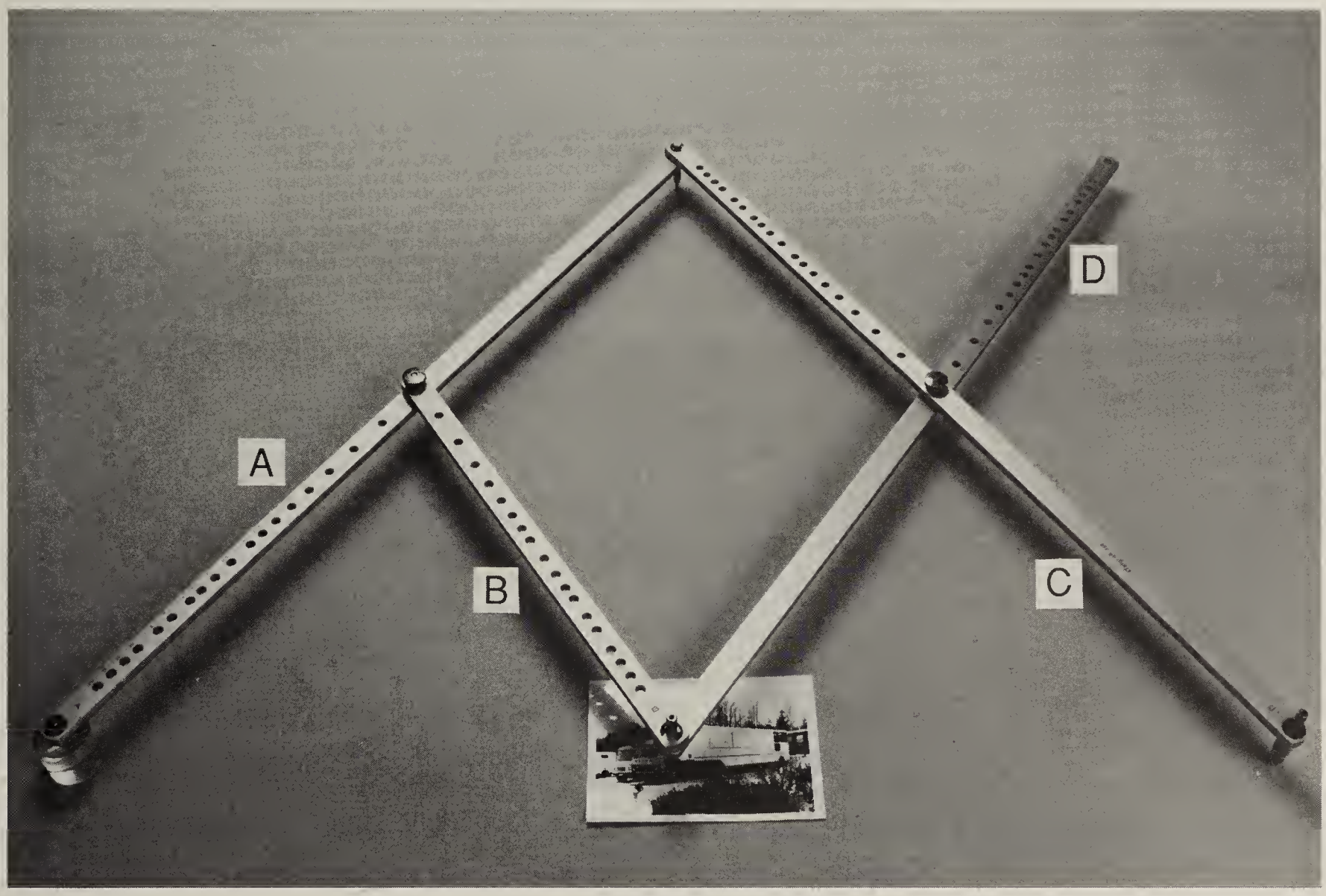
Draw a grid directly over an original drawing or on a transparent sheet of paper that is fastened on top of the drawing. Then make another grid on a separate sheet of paper, increasing or decreasing the size of the squares, depending on the desired size of the final display. For example, for an enlargement, make .8 in. (2 cm) squares on the original drawing and 1.6 in. (4 cm) squares on the second grid sheet.

The grid over the original drawing will divide the drawing into small sections. Particular points can be established by observing where the lines of the drawing cross the grid lines. These points can be marked on the second grid and the lines of the drawing reconnected to make a larger or smaller picture or map.

The Pantograph

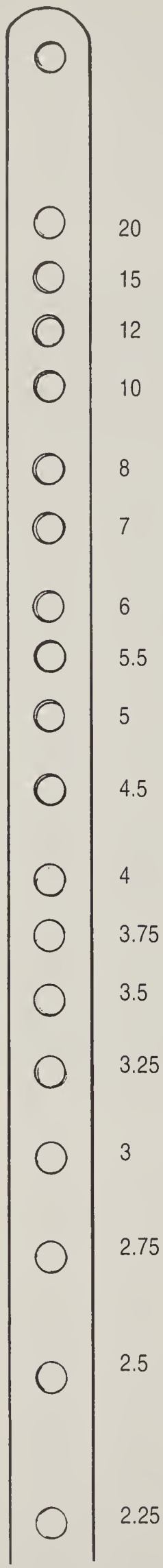
A pantograph is an instrument consisting of four arms jointed in parallelogram form. It is used to copy maps, pictures, and diagrams on any predetermined scale.

The specifications for a pantograph are:



A pantograph consists of four thin pieces of wood, metal, or plastic. On an average instrument, all arms are of equal width, .6 in. (1.5 cm) with a thickness of .2 in. (.5 cm). Three of the arms—A, C, and D— are equal in length, 23.6 in. (60 cm). Arm B is one-half the length of arms A, C, or D, or 11.8 in. (30 cm). The center pin in arms A, C, and D is located in the middle of the arm, 11.8 in. (30 cm) from the ends of the arm.

The pantograph's anchor can be a screw that is fastened onto a tabletop or a sharp point that can be pressed into the wood of a tabletop or a drawing board. The tracing stylus can be made from a blunt nail. Its purpose is to follow the lines of an original drawing. The drawing tip can be a lead pencil or a pen, which is mounted in a hole at the end of one of the arms.



The figure shown at the side of this page is from a 23.6 in.(60 cm) pantograph arm, reduced 78 percent. The numbers beside the holes indicate a reduction or increase in the size of the desired drawing, depending on how the arms are assembled.

The following are ways to use a pantograph:

- To enlarge a picture or map, place the tracing stylus at point BD. Place the lead pencil on the free end of arm C.
- To reduce a picture or map, place the tracing stylus at the free end of arm C and the pencil at point BD.
- Attach the anchor of the pantograph to a table or board. Be sure that the stylus, pencil, and point AC (which should be equipped with a round-tipped stylus or a foot) hold the pantograph level. This is important—adjust it if necessary.
- Place the original picture or map beneath the stylus point. Place drawing paper beneath the pencil point. Test the tracing stylus at the outermost points of the picture or map to see if the enlarged or reduced image comes within the area of the drawing paper. Tape the picture or map and the drawing paper in place.
- The larger the desired enlargement, the closer the original picture or map must be to the anchor point.

Projectors

A projector is an optical appliance that can generate and direct the image of a picture or map onto a wall, tabletop, or other surface. The size of the image can be varied, from an enlarged to a diminished format. There are several different types of projectors for nontransparent printed matter.

Epidiascope

An epidiascope is an optical device for projecting a magnified image (inkprint book page or map) onto a screen or wall. This kind of machine is often used in schools. An enlarged image can be projected onto paper fastened to the wall. The image can be redrawn directly onto the paper.

Drawing Camera

A drawing camera is a projector that fastens onto a wall or tabletop. It enlarges or reduces the size of printed matter three to five times the original size and is suitable for redrawing an original sketch directly onto the desired background material.

One type of epidiascope.

To use a drawing camera, insert a sketch or printed matter into the machine, and adjust the projection to the desired size: larger, smaller, or the same size. Place the background material within the projection area, and trace the projected lines onto the background material. If the display is to be embossed, use the technique for tracing a negative image.

Office Copying Machine

Many photocopying machines have the capacity to enlarge or reduce materials. To produce material in a desired size, it may be necessary to reproduce several different copies of the material, one from the other. If this is the case, make allowances for a slight change in the relationship of lines that have been recopied (enlarged or reduced) several times. This is important only when several different images are meant to fit together in a foldout display, such as maps or diagrams.

Reprocamera or PMT

A reprocamera or photomechanical transfer machine (PMT) is a photocopying machine that enlarges or reduces the size of printed matter by producing the image of the matter on a photographic print. This is the most expensive way to change a display format. However, the result is a better-quality print than one that has been enlarged or reduced in an office copying machine, and the problem of the distortion of lines is eliminated.

There is a hazard involved in enlarging or reducing material. The lines on an enlarged picture or map will increase in width in

A reprocamera or photomechanical transfer machine.

proportion to the increase in size of the layout. This may mean that the lines become too thick to use the enlarged copy of the original print for a microcapsule paper display. Reducing the size of an original layout may make the lines too thin for a satisfactory relief figure on microcapsule paper. These two problems can be solved by using a light box or table. Place a sheet of paper on top of the original graphic material and redraw the final layout. The light underneath the paper will enable the original material to show through the second layer of paper.

BACKGROUND MATERIAL

The choice of background material for a display depends on the production technique to be used and the number of displays you want to make—a single display or one that is mass-produced. Cardburr and flannel boards, metal boards for magnets, cork, plastics, cardboard, thin wooden veneer, braille paper, embroidery canvas (with or without a paper backing), metal foil, sandpaper or other textured surfaces, and microcapsule paper are possibilities. An image can be transferred to the bulk of these materials by using one of the methods already described in this chapter.

Colored paper, cardboard, and materials of various kinds tend to attract the eye when they are used together in a buildup master. Two different colored forms that border each other on the same plane give the impression that they are two completely defined areas. If this happens with a master, it may not be discovered until a plastic copy of the display is made in a vacuum-forming machine. It is easier to construct a master with all-white paper and cardboard and eliminate such problems.

ADDITIONS AND CHANGES

Not all displays can be changed as easily as those made on Cardburr, flannel, or magnetic boards—materials to which new items can be added and subsequently removed at will. This does not mean, however, that once a display has been made it cannot be altered.

Making Changes on a Paper Buildup Master

- Symbols, lines made of string or tape, and forms glued on the surface of different background materials can be removed with a scalpel. Sand the rough area left by the removed object with the finest grain sandpaper and shellac the area. Repeat this process until the area is completely smooth. It is advisable to dust talcum powder over the area before making a new plastic copy.
- Wire and thread or string pierced or sewn through background materials leaves holes when removed. The holes can be filled with a quick-drying putty applied with a spatula or

palette knife. The excess putty is scraped away immediately before it is dry.

- Indentations cut into background material can be filled with putty or with cardboard cut to fit the area. Shellac the putty-treated area if it is extensive and there is a risk that the putty will flake away.
- New lines can be embossed with different types of spur wheels or a drawing stylus, or they can be made with preglued string or thread.
- Dots for cities on maps can be punched out of cardboard, leather, cork, metal, or preglued cotton cloth. To preglue cloth, saturate it with glue or a combination of glue and water. Press as much glue as possible out of the cloth. Flatten the cloth with a rolling pin or a metal pipe or run it through a hand-mangle. Hang the cloth up to dry. The stiff, dry cloth can easily be punched with a hand punch or cut with scissors. The saturated cloth will not absorb more glue when it is to be mounted on the display. This process ensures a firm bond between the cloth and the background, allowing an equal amount of glue to cement the two surfaces.
- Braille text and other embossed symbols can be removed by placing a heat-resistant tape on the back of the display and pressing the dots into the tape. If the dots still leave a raised surface, use the shellac and sandpaper process, or shave down the embossed area with a scalpel before sanding it.

Making Changes on a Metal Foil Master

One of the advantages of metal foil is that patterns and symbols can easily be added or removed. Relief areas can be flattened out by placing the foil on a smooth, hard surface and rubbing away the unwanted area with a flat piece of wood, metal, or plastic. Be sure that the work area beneath the foil has no texture; wood grain or any coarsely textured material will leave an imprint on the metal foil while it is being rubbed. Once the unwanted area has been removed, the foil can be reworked.

Making Changes on a Microcapsule Paper Display

The original drawing can be redrawn or retouched. Make a copy of the original drawing in an office copying machine.

Make changes on the copy. File the original display for future use; it may be needed again. To remove information, cut away undesirable areas with a knife. Mask out unwanted areas with white paper glued onto the copy, with white masking tape (correction tape), or with opaque white poster paint.

To add information you can do the following:

- Redraw the area directly on the display with black ink.
- Add texture by rubbing on dry-transfer patterns of Letraset or Mecanorma type, or glue in texture enlarged or reduced in size on an office copying machine and cut to fit the display.
- Rub dry-transfer braille characters, inkprint letters, lines, and symbols onto the display. Braille dots can also be made with an inking pen or a felt-tipped pen and a stencil.
- Cut to size and glue onto the display information that is on a separate piece of paper. The joy of altering drawings that can be recopied in an office copying machine is that the edges of the new areas seldom show in the copy. If they do, simply paint them out with white paint.

Making Changes on a Swelled Microcapsule Paper Display

- Changes made on an already swelled microcapsule paper display can be made by carefully scraping away the misplaced braille dot or line with a scalpel. Gently scrape down the sides of the remaining ridge that may be left after this operation. Always test your changes with your fingers!
- Information can be added to the swelled display by using lead pencils or felt-tipped pens (see "Microcapsule Paper," Chapter 2). Reheat the paper after the addition has been made. The paper can be reheated moderately two or three times without losing its sharp lines. The added items will swell to the same elevation as those items already on the paper.
- The addition of dry-transfer letters and patterns is not recommended for microcapsule paper that will come in direct contact with an infrared heater. The thin film may burn.
- Sandpaper or other textured materials can be glued onto a display after the last "swelling" process. Metal paper fasteners can be pushed through the paper to mark particular places on maps; they are easily removed or moved.

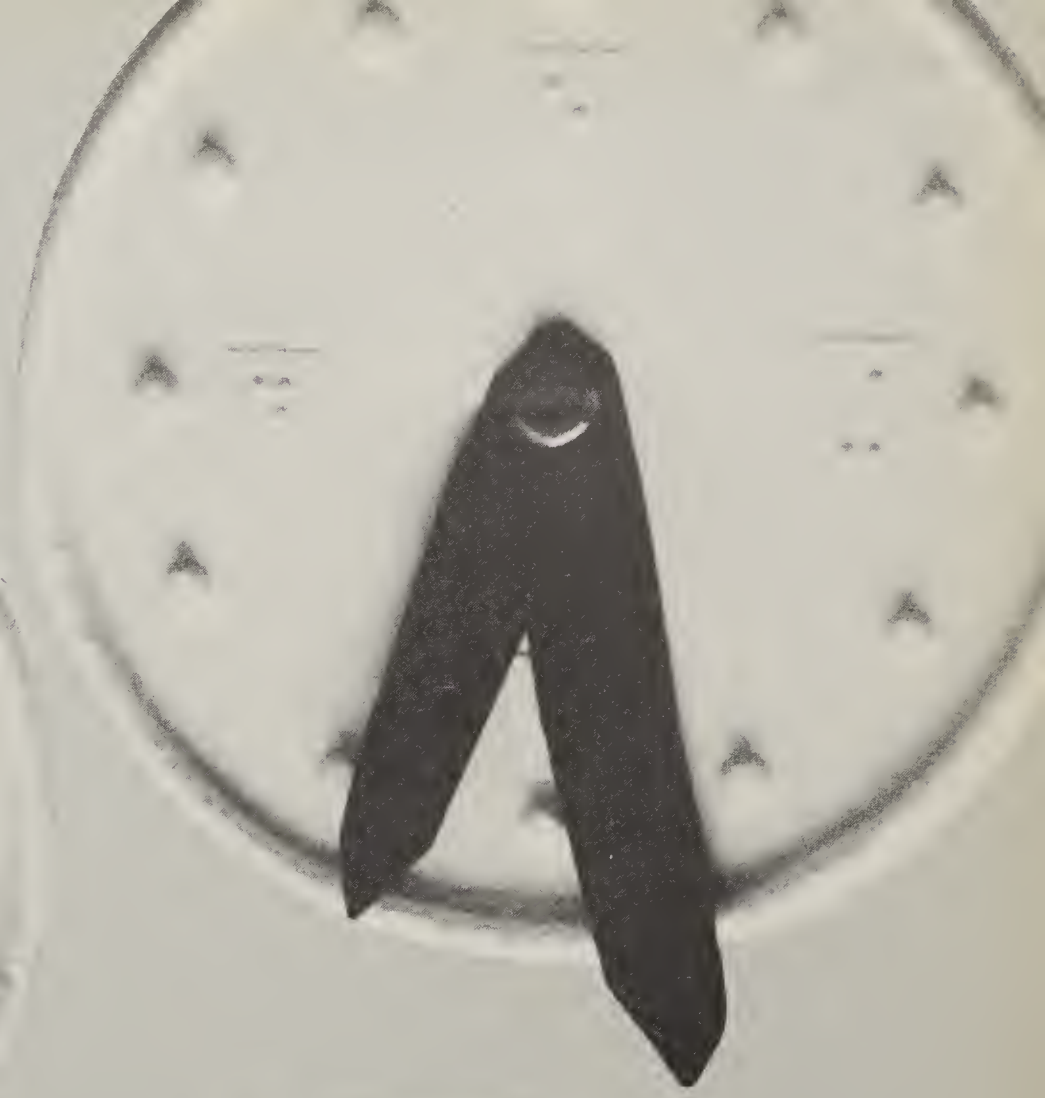
- Color can be added for readers with low vision by using felt-tipped pens. The use of water colors is not advisable.

Making Changes on Plastic Copies from a Master

- Symbols, lines, and dots can be embossed into a plastic copy with a spur wheel and a freehand drawing stylus.
- Punched-out dots of various sizes and materials can be glued into place. Metal paper fasteners also make dots; place tape on the back of the display before inserting the fastener through the plastic copy. The advantage of the fastener is that it can be moved or removed at will.
- Lines symbolizing routes or whatever else can be sewn into a plastic copy. Reinforce the back of the plastic sheet before sewing.
- Glue, forced through a small opening of a tube or bottle, makes an excellent raised line, but it takes time to dry thoroughly. Use a quick-drying glue.
- A plastic substance, used in glass painting to make a relief line between various colors, forms a permanent line when extruded from its tube. This product, produced in several countries, has many different names, which usually include the words, "contour paste."
- Hi Marks is the commercial name for a brightly colored resin that can be squirted from a tube into a desired position to produce relief lines or points. This product becomes hard within minutes and produces distinctive tactile information. Copies can be produced by the vacuum-forming process, but care should be taken not to apply too much heat. The vivid orange color of this product makes it a practical aid for many readers with remaining vision. Further details can be obtained from the American Foundation for the Blind or the Mark-Tex Corporation (see "Sources of Materials and Equipment," Appendix 3).
- Textures, such as sandpaper and other relief materials, including microcapsule paper textures, can be added to a plastic copy permanently (with glue) or temporarily (with rubber cement, adhesive paste, and the like).

- Braille can be added by using a slate and stylus, by gluing brailled strips of paper or metal foil onto the plastic copy, or by embossing braille on plastic tape (dymo tape) that can be stuck onto the display.

Important! If information is added to or removed from a display that has already been completed, make sure to change the key to that display as well.



CHAPTER 8

Mathematics, Graphs, and Diagrams

Technical material contains a tremendous quantity of graphs and diagrams. To be able to make this information available to visually impaired readers, it is necessary to understand some of the problems involved and their possible solutions. A milestone in work in this area is *Guidelines for Mathematical Diagrams* (Braille Authority of North America, 1983), which is especially valuable to people who transcribe or illustrate materials for blind persons.

Although information relating to graphs and diagrams constitutes the bulk of the material in this chapter, it is also suitable to a wide variety of fields, including physics, chemistry, economics, engineering, and geography. The guidelines already described in other chapters for both pictures and maps are applicable to this chapter and will be referred to throughout the discussion. The techniques presented here are by no means the only way to produce a serviceable relief. New and better ideas and techniques are being developed at a rapid rate. This chapter is meant to help you to start thinking about the possibilities. You are the one who is aware of your readers' needs and capabilities.

For the visually impaired student to be able to read graphs, a systematic approach should be worked out between the teacher and the student. Graphs are difficult if not impossible to understand unless the purpose, layout, and symbols are explained before study begins. This explanation may necessitate a talk with the teacher or the student or a short written comment accompanying the relief graph. A series of

OPPOSITE PAGE: Tangible clock faces are an example of how tactile graphics can be effective in helping students learn mathematical concepts. The clocks shown here are outlined with string and have movable plastic hands.

graduated graphs, from very simple to quite complicated ones, could be presented at this time. The use of a freehand drawing board should not be overlooked as an excellent aid on which to build up a base knowledge of the workings of graphs. The possibility of using several graphs in a step-by-step technique should also be considered if the amount of information to be presented warrants it. This may include the same graph with or without a grid system.

Visually impaired students can follow classroom instruction more easily if they are supplied with material that is similar to that of their sighted classmates. It is difficult, however, to make tactile graphs and diagrams that are similar to their printed counterparts. The printed material often deals with abstract information that is made more understandable for the sighted reader through the use of color, shading, and perspective. For the blind or visually impaired reader, these elements must be transposed into textured areas, frontal or profile plane drawings, and step-by-step displays. The purpose of the relief displays shown in this chapter is to illustrate the relationships among the individual components of the graphs and diagrams so that, by comparing these parts, the reader can better understand the information that is presented and the techniques that were used.

As always, keep in mind the inability of blind readers to disregard unimportant details or information. All the relief symbols that pass beneath their fingertips are registered in their minds. Lead your readers through an uncluttered display, stressing only important information in relation to its priority. It should not be necessary for the curves in a graph to battle their way through a dominant grid system, and line tracing by the fingers should be made as easy as possible through the elimination of prominent textures from the area. Be consistent when making a series of related or unrelated graphs for a particular student. This will involve using the same type of grid system, the graduation of the number system from left to right or right to left, from top to bottom or bottom to top and, if possible, a similar symbol system and a similar placement of symbols in the graph key. A summary of guidelines for the production of graphs and diagrams appears later in this chapter.

TO DO OR NOT TO DO?

Relief graphs and diagrams complement the printed text, helping the reader to organize that information. The problem: Are they necessary?

Produce a diagram or graph if:

- It contains valuable information that is not included in the text.
- It makes the text more understandable because of the layout or presentation of the material.
- It is directly related to the text--if the diagram or graph is discussed point by point in the text and the reader's participation is required in answering questions or solving problems.

Do not produce a diagram or graph if:

- The text is self-explanatory, and no additional information is presented by the diagram or graph beyond that already stated.
- The proposed diagram is so simple that a few lines drawn by the teacher or assistant on a raised-line drawing board could explain the figure.
- An oral explanation from the teacher or assistant would be sufficient.

A decision in the negative does not relieve you of the responsibility of informing the reader that a figure is missing. The transcriber, who writes the text in braille, should be told that a particular diagram or graph is not to be included. The transcriber should write the text that accompanies the missing figure in an appropriate place on the page, informing the student that this figure is not included in the relief display and adding any instructions to the reader or teacher that may be necessary.

A decision in the positive can be treated in several ways, which are discussed in the following section. Here, as in other chapters, the figures and displays shown are derived from my work in Sweden. Their text is therefore in Swedish, and the numerical values used may reflect metric system values and Swedish or European mathematical notations.

TYPES OF DISPLAYS

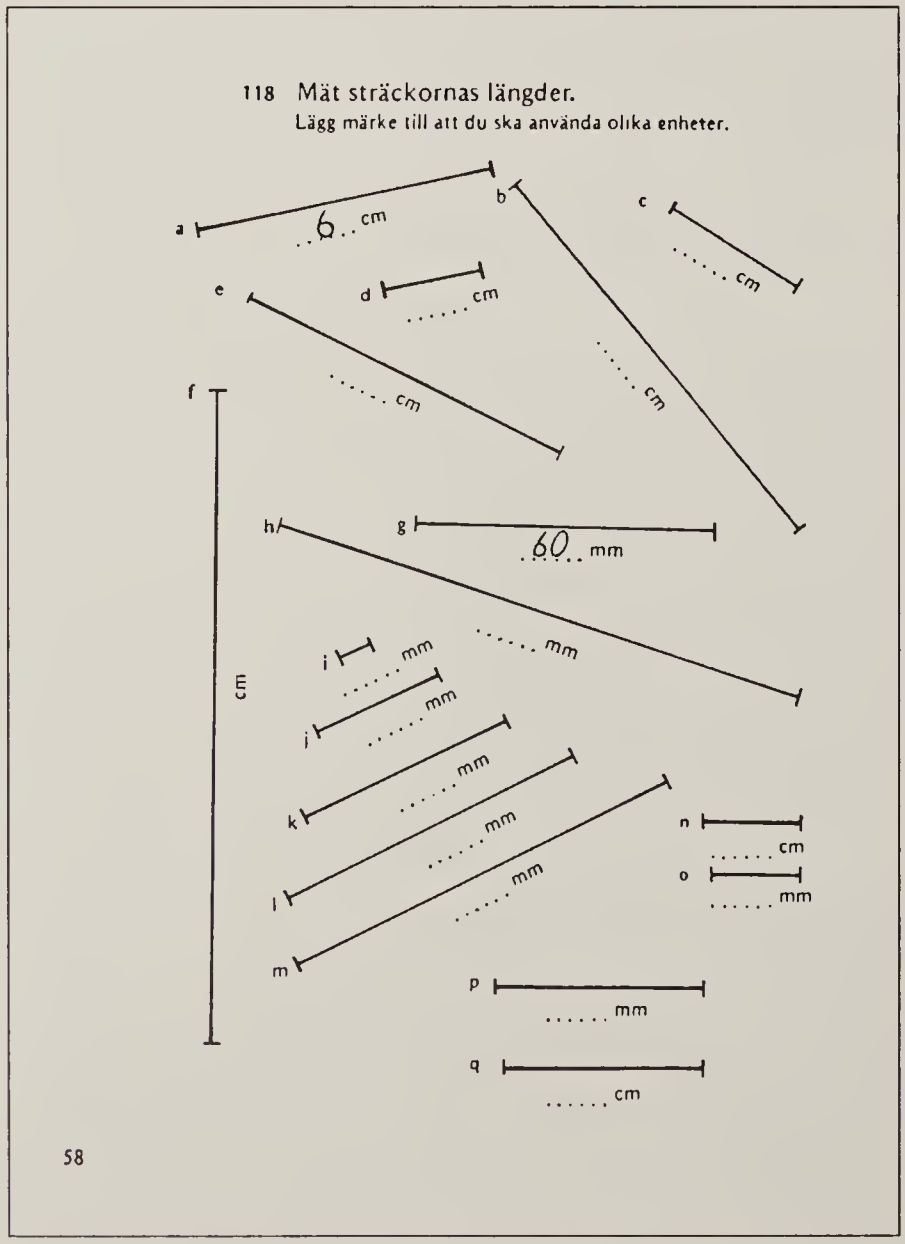
Type 1

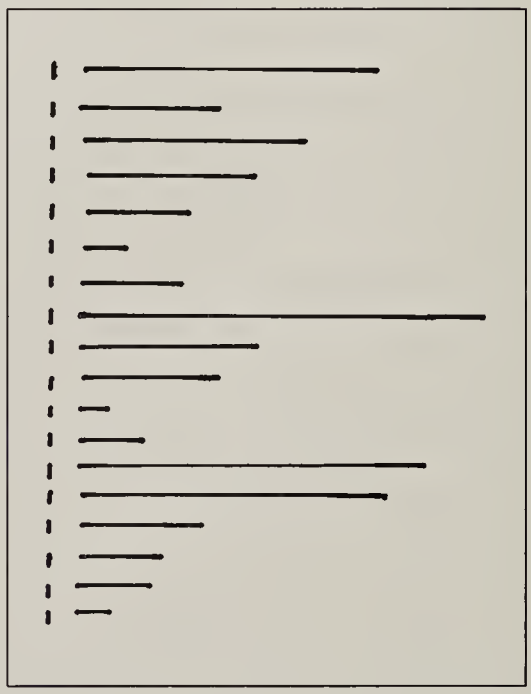
One type of display closely follows the original content of the printed material, repeating the same size of the elements in the display but not necessarily their same positions.

An exact copy of the inkprint figure is necessary when the reader is asked to measure certain elements. However, the layout should be changed to facilitate finding and measuring the lines, as it has, for example, in the illustration shown here (see A). In such cases, number each line so the student can write his or her answers on a separate page.

Some teachers prefer a duplication of the objects shown in the inkprint layout (see B and C), especially when the class works with both three-dimensional objects and printed pictures. The problem is to measure the length of the objects, not their form. The simplest presentation would be one similar to the immediately preceding layout (see A), using lines only.

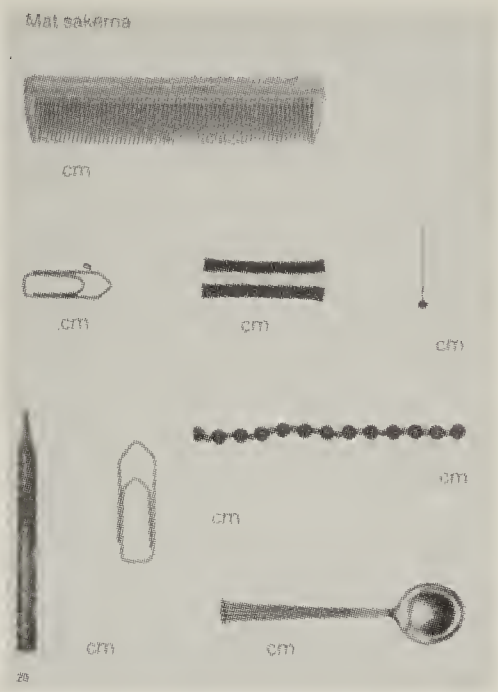
A. A display (*right*) in which the original position of the objects in the inkprint layout (*left*) has been changed but their size has been retained.



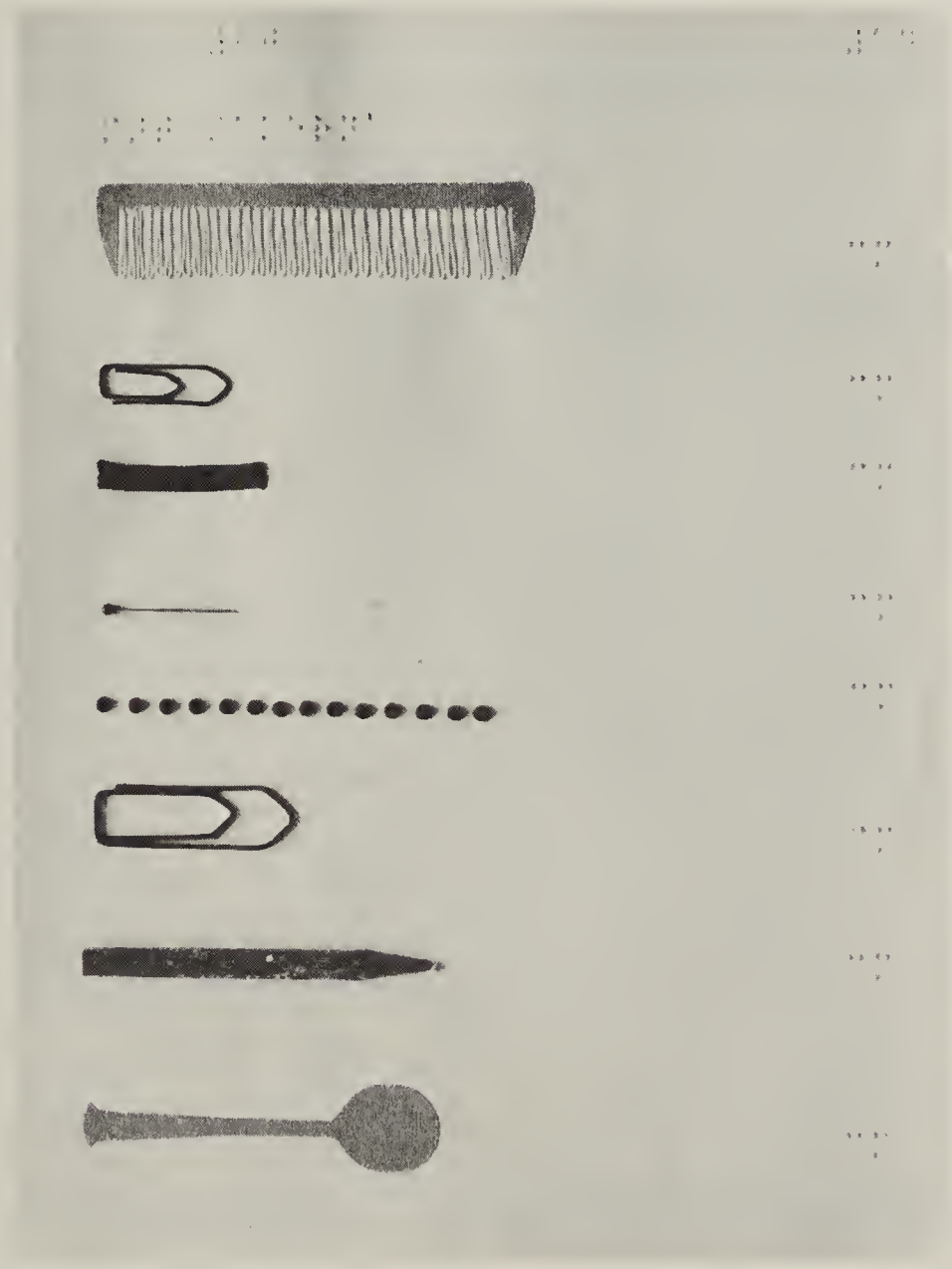


The relief display of the objects shown here (see C) followed the wishes of the teacher; it is more or less a copy of the printed page. The space for answers has been moved to the right side of the page to facilitate answering the problems on a braillewriter. Using this system is possible only if the master has been made in low relief.

It is as difficult to measure an object when the display is in the braillewriter as it is to adjust a plastic display in the machine so that the picture and answer are on the same line. In this case, I would suggest removing all the centimeter symbols in braille on the right side of the page, numbering the items represented, and telling the student, in a separate section, to write the answers on a separate sheet of paper.

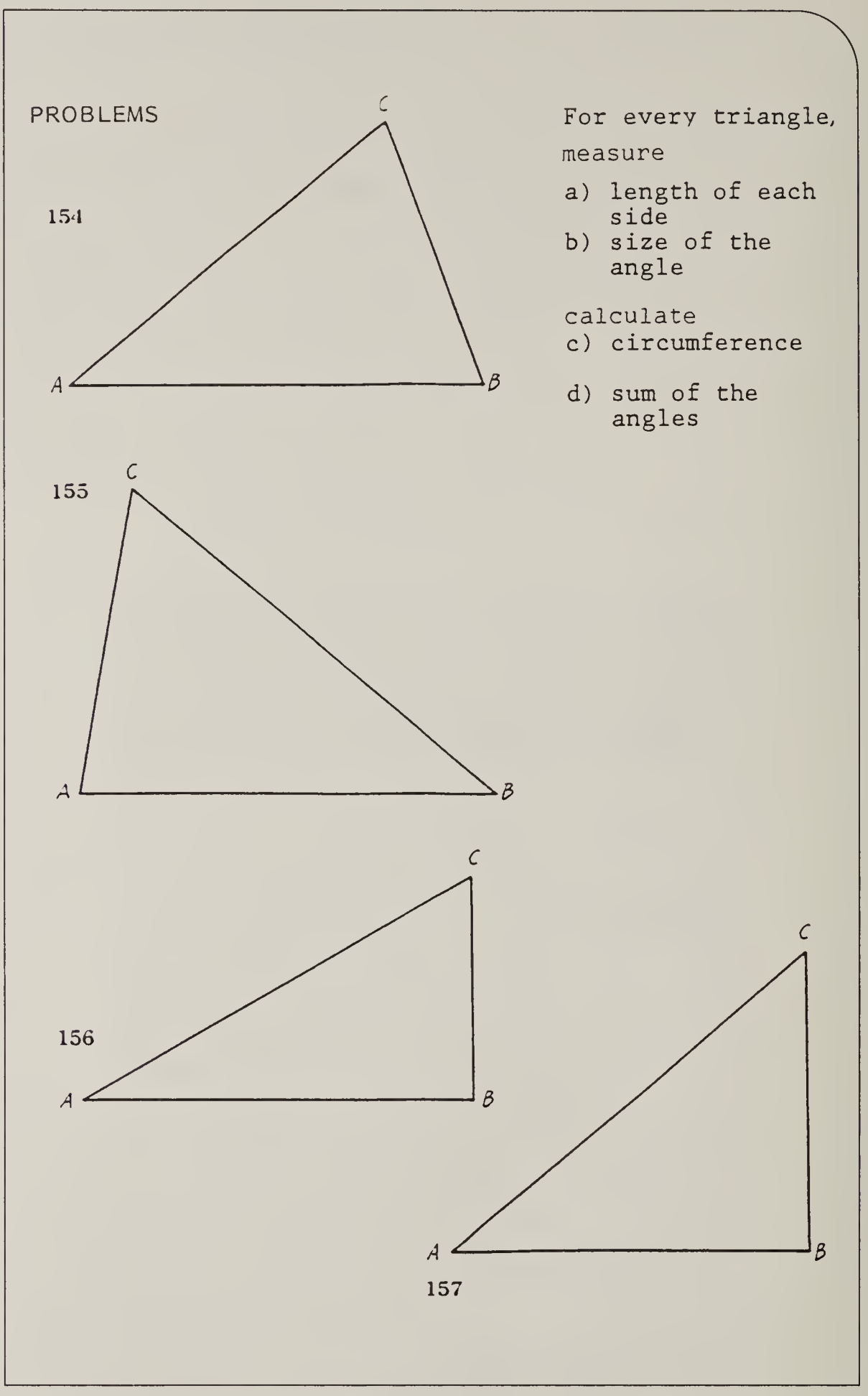


B. An inkprint layout of objects to be measured in centimeters.



C. A relief display of the inkprint layout.

In cases in which geometric figures are to be measured by the reader for such elements as overall size, length of sides, or width of angles, as shown in D on the next page, relief displays should be the same size as those printed in the textbook.



D. A textbook illustration of geometric figures.

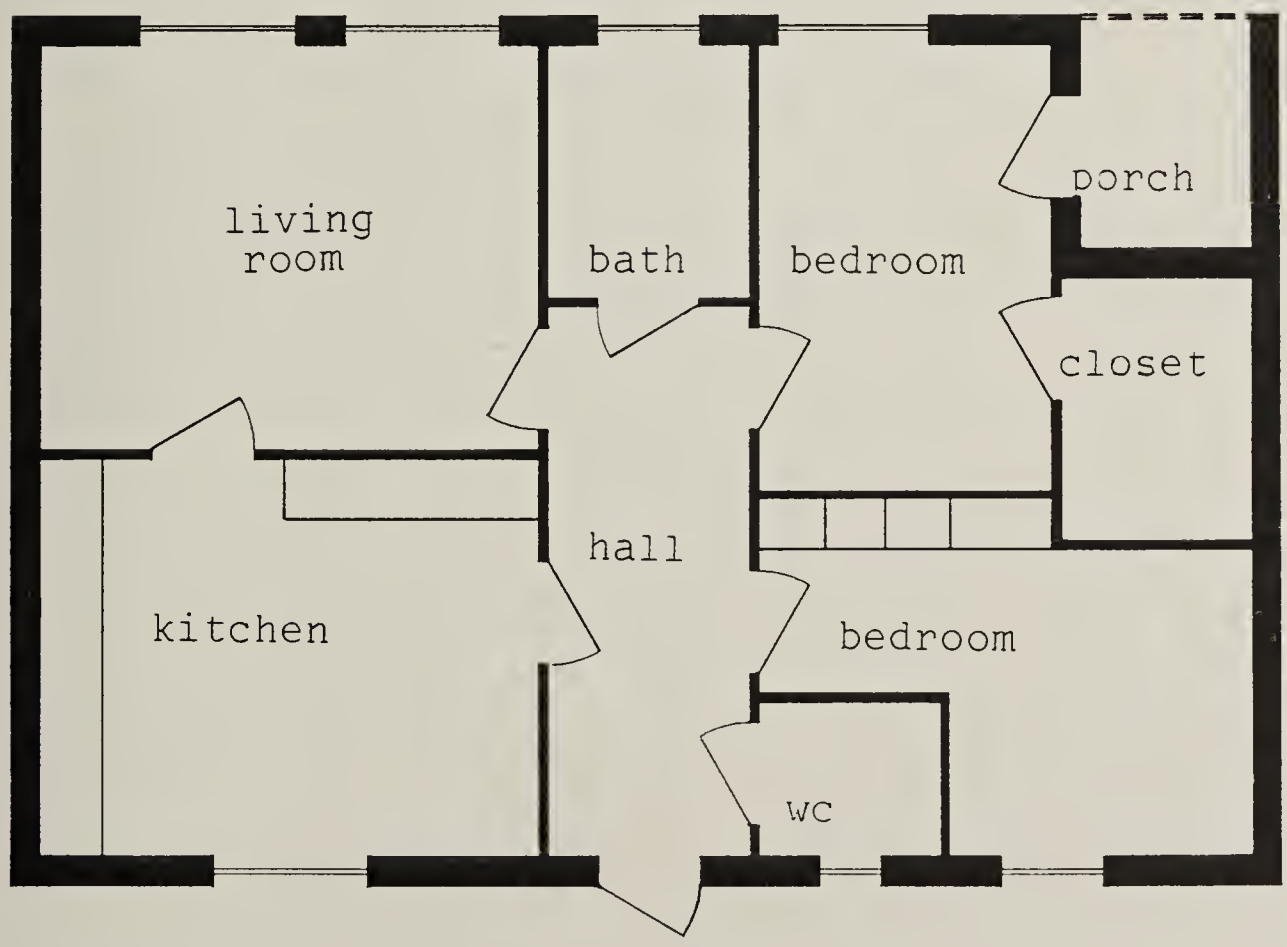
The following are suggestions for buildup masters:

- Make the form or line to be measured high enough above the background material so the reader can easily use a relief ruler or protractor.
- The placement of braille labels will be determined by the

problem to be solved. If measurement of the perimeter of the figure is required, place the braille symbols inside the perimeter of the figure so that they will not be in the way of a ruler.

- If you are using a braillewriter, write all braille symbols on the background material before adding cut-out forms and other materials to the display. A slate and stylus may be easier to use for this purpose (see "Labels," Chapters 4 and 6; for information on embossed masters, see "Embossed Paper Displays," and on microcapsule paper, see "Microcapsule Paper," Chapter 2).

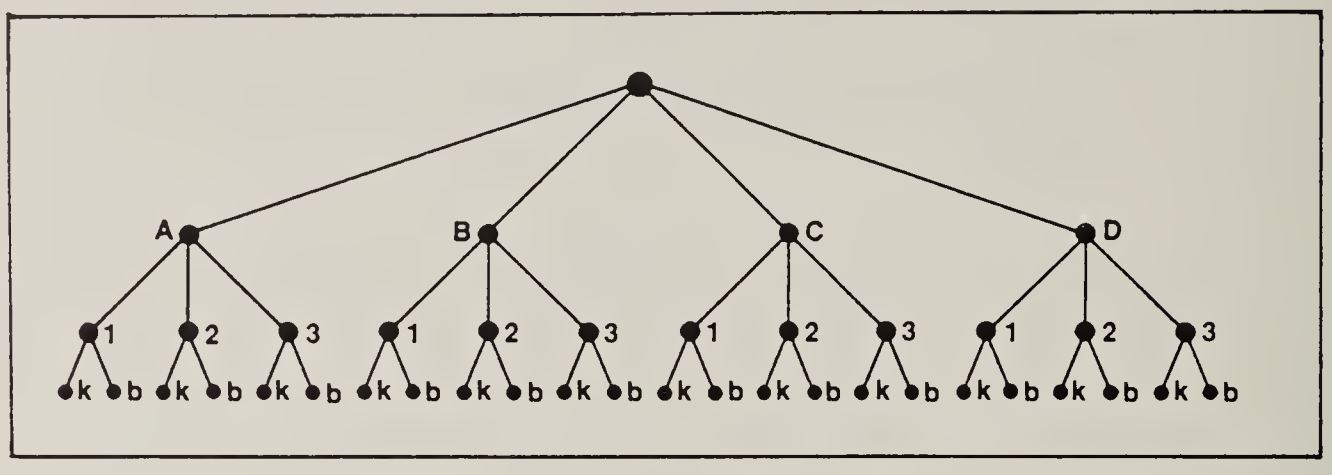
The floor plan of an apartment illustrated here appeared in this size in a textbook. The scale of the drawing is 1:100. The problem given to students was to figure the floor area of each room. Consequently, the relief display had to have the same dimensions.



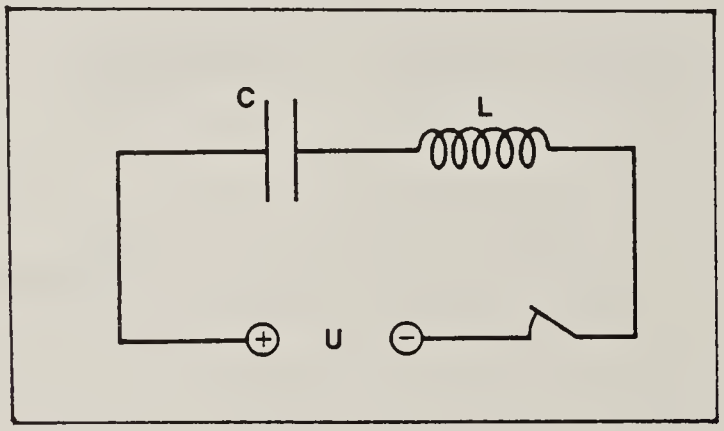
Type 2

Another type of display closely follows the printed material in content and layout but not in the size of the figure. A great many graphs and diagrams fall into this category. Although enlargement of the original material may be necessary, the

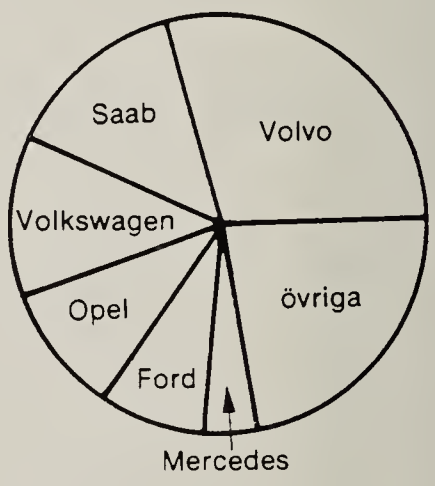
only change that should be made within the actual figure is the exchanging of printed letters and numbers (as in A, B, and C here) for braille symbols. The amount of space taken up by a braille character that is surrounded by a sufficient amount of white space—a minimum of 1/8 in. (3 mm)—often determines the size of the enlargement of the figure (see "Basic Principles," Chapter 3).



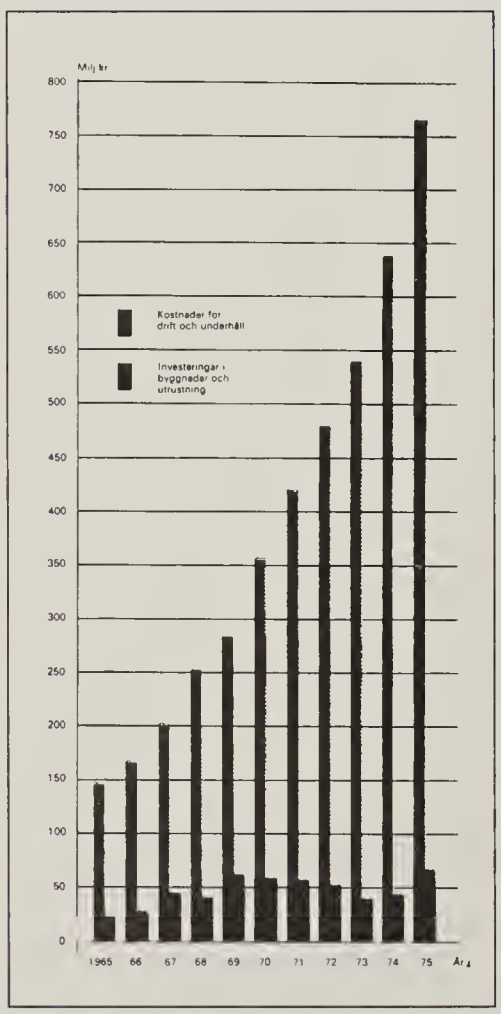
A.



B.



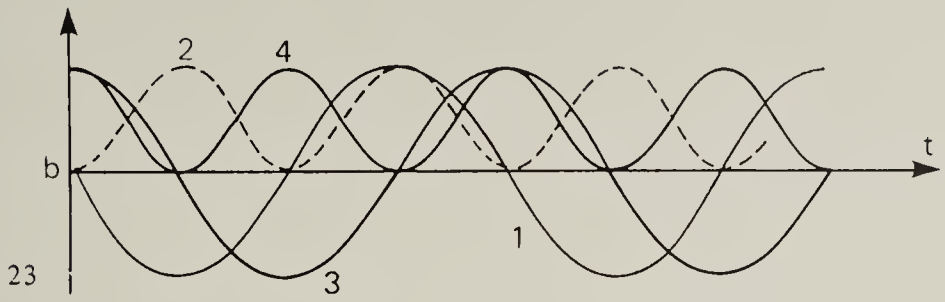
C.



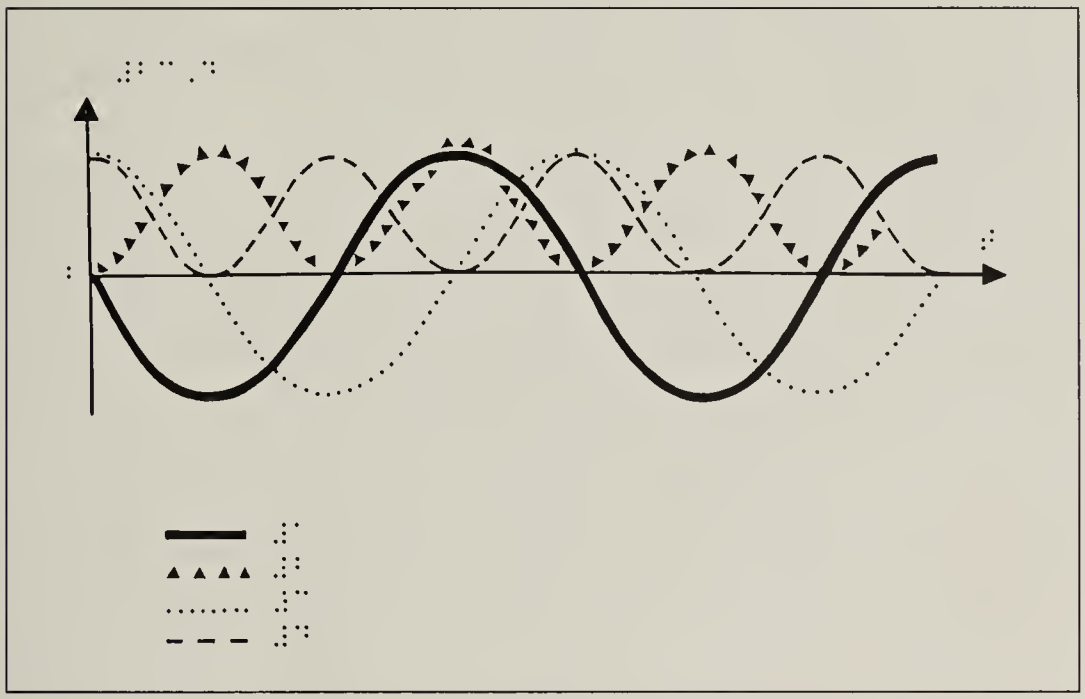
D.

In some instances in which printed letters need to be converted to braille, move the key to a space beneath or to the side of the graph. As in the example (D) shown at left, if the letters remain where they are, it is confusing, and they will become an integral part of the graph.

The relief display on microcapsule paper illustrated on the next page (see F) closely follows the printed material in content and layout. The original diagram (see E) appeared in a third-year physics book (Adolfsson & Kronquist, 1978), and lines 1 and 2 were printed in light-blue ink. The number of crossing lines in the original and the inability of visually impaired readers to discern color made it necessary to break this figure down into a step-by-step diagram.

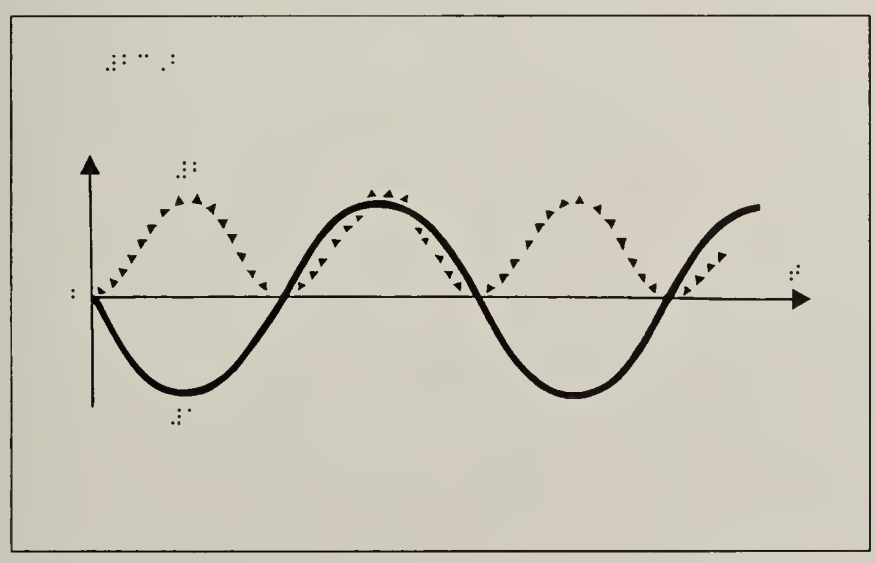


E. The original diagram.

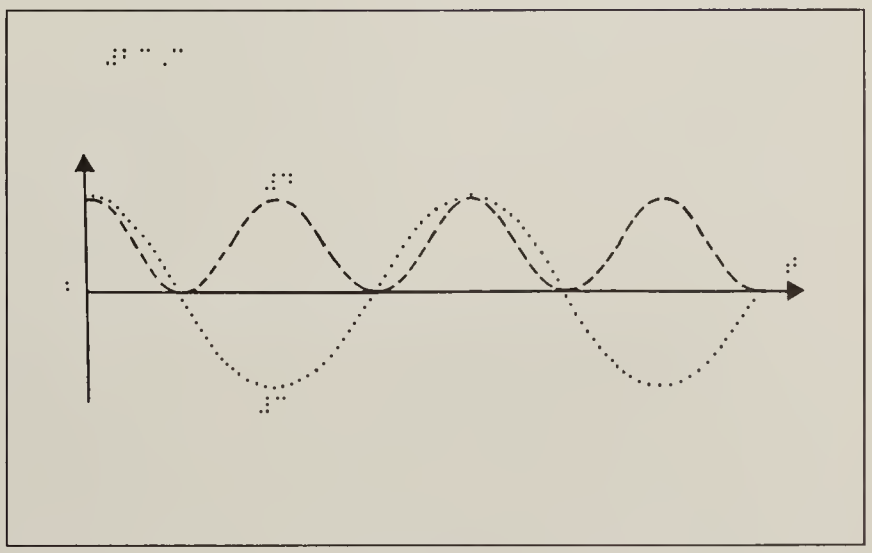


F. The microcapsule paper display.

Whenever a great deal of information is presented in a limited area, a step-by-step process is highly recommended to facilitate the tracking of lines by readers and to eliminate confusion. It is interesting to note that some students wanted the complicated diagram to be presented first (see F), to be followed by steps 1 and 2, while others preferred to have steps 1 and 2 first, to be followed by the more complicated diagram.



Step 1.



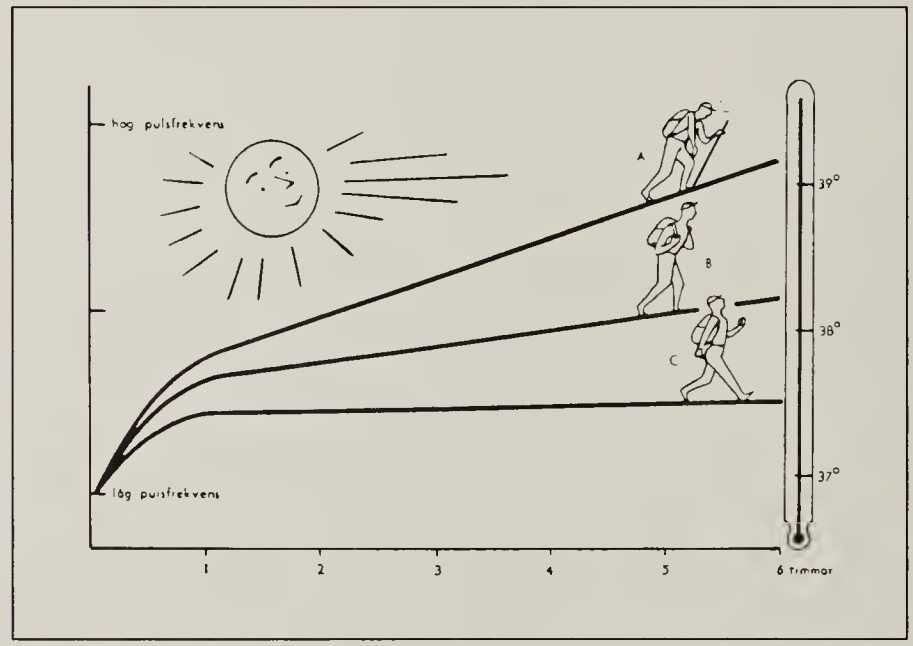
Step 2.

It would seem that the order of presentation is a matter of personal preference. Therefore, it is often advantageous to have all the relief diagrams, pictures, and maps for a particular book or course in a loose-leaf binder. Students can then arrange them as they wish.

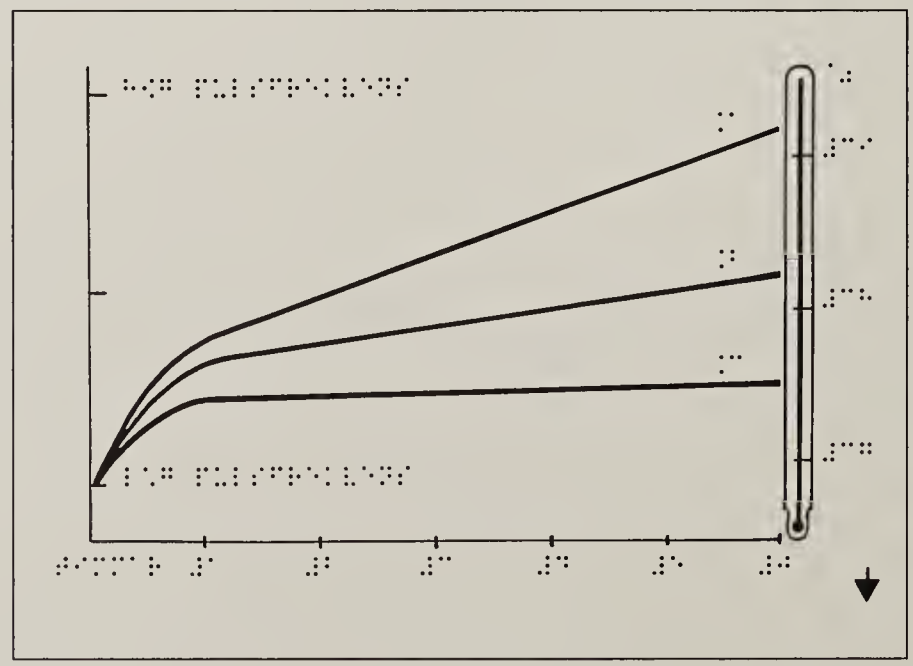
Type 3

A third type of display closely follows the printed material in information content. However, the layout, the size of the elements, and even the form of those elements can be changed.

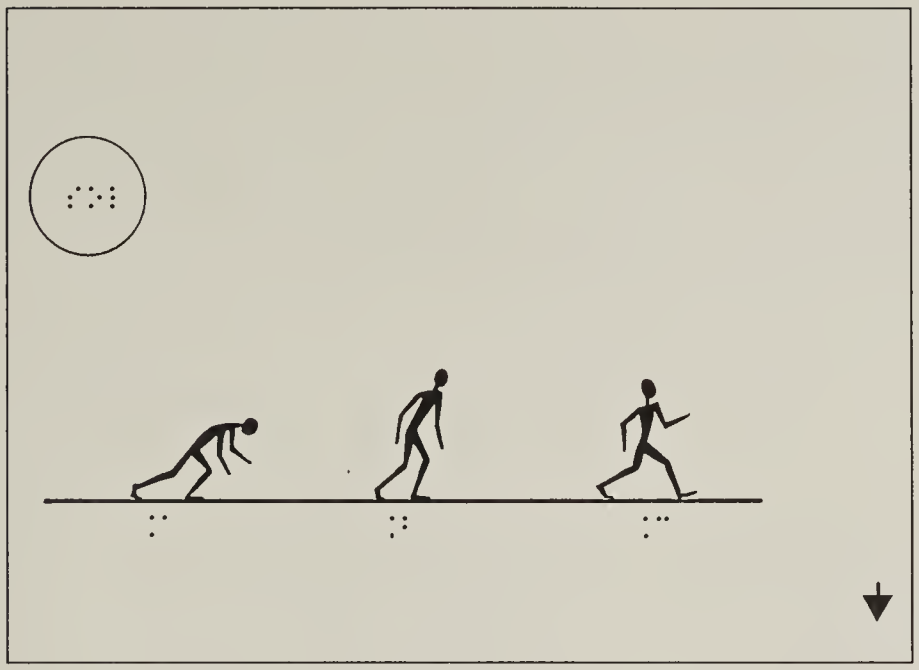
Information can be moved from one area to another. For example, the relief display shown below was made into a double-page spread. The figures of the men and the sun that appeared in the original textbook illustration (see A) were moved to a "key" (see C) on a page that faced the diagram (see B).



A. The original textbook illustration from *Bättre Kondition* (Åstrand, 1978).



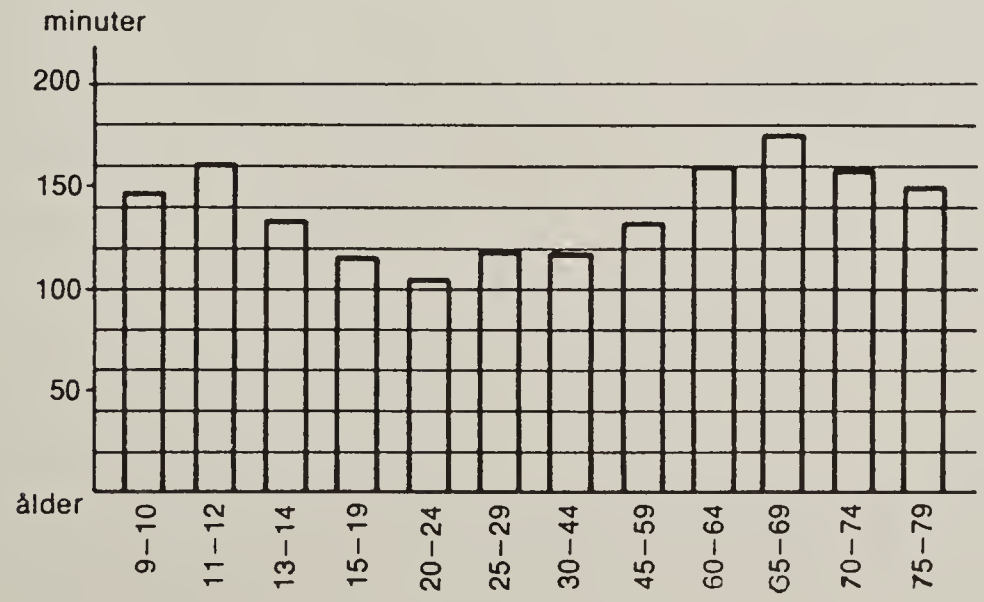
B. The relief diagram on microcapsule paper.



C. The key to the relief diagram.

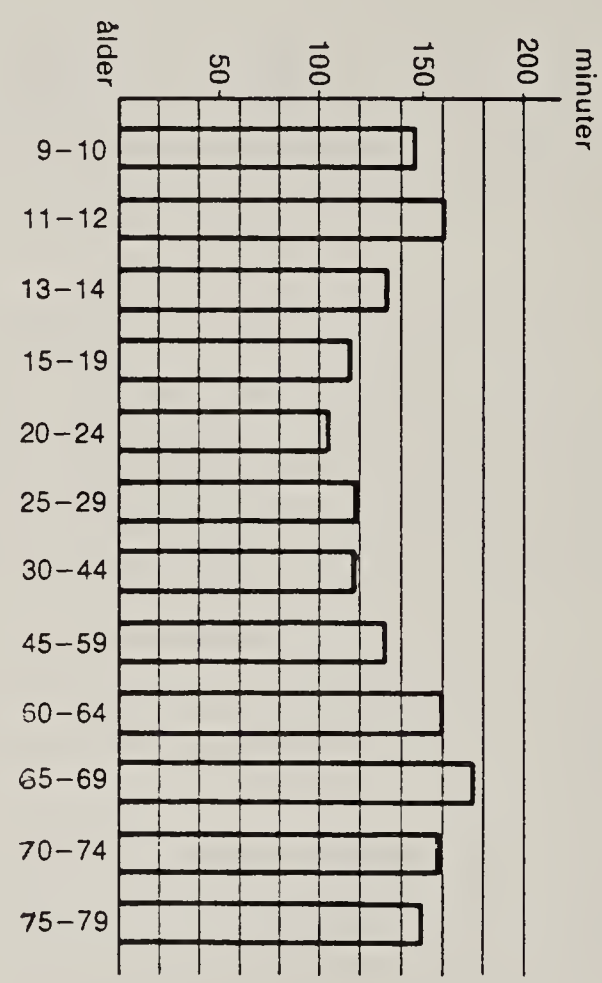
Often, the position of a diagram can be turned around. The layout of the diagram can be changed from a horizontal position to a vertical one to fit the page format. This may be necessary in order to make room for the braille text or to accommodate the form of an enlarged figure. Be careful to make sure that the information presented has the same meaning if the diagram is turned around—curves that should go up may go down!

The graph shown below (from Nyman, Emanuelsson, Bergman, & Bergstrom, 1980) of the age groups and listening times of radio listeners in Sweden is easily read both horizontally and vertically. But if the graph is in a horizontal position, the braille text would be in a position that would necessitate turning the page so that it could be read. Avoid placing braille text in this way. In this example, you could substitute the numbers in the age groups (*ålder*) for single letters—A, B, C, and so on—and use a key.



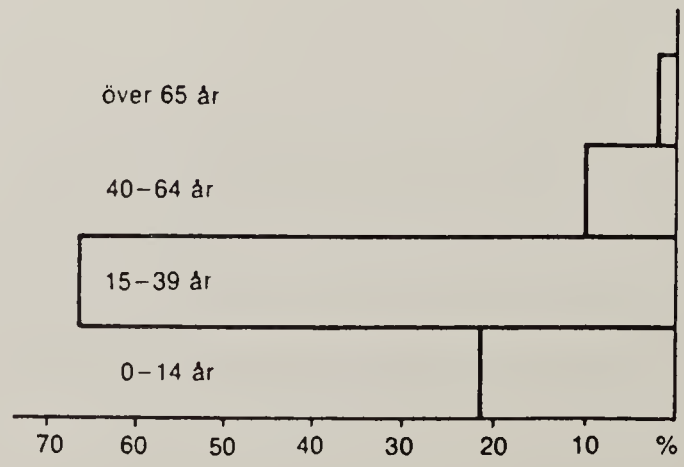
Horizontal position.

If the graph is placed vertically, there is ample space to write out the age-group numbers, and a key is not necessary. The figures 50-200 and the word *minuter* should be turned to a horizontal position. They can either be moved to the bottom of the graph or remain where they are.

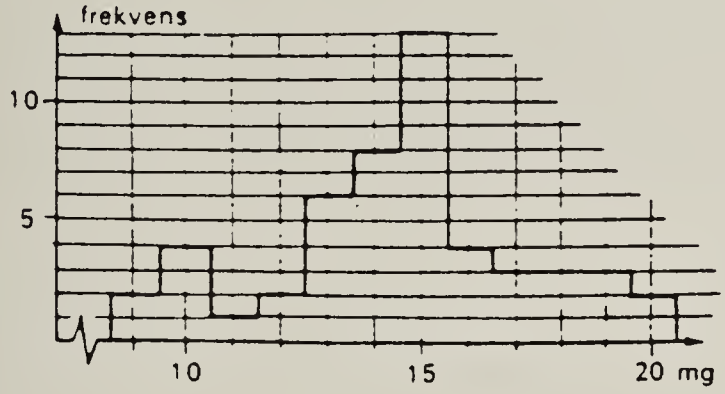


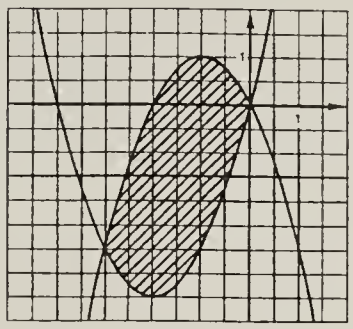
Vertical position.

The next graph shown here is strange to the eye as well as the fingers and should be turned to a vertical position. Blind people read from left to right. This graph is not set up in a customary graph layout and could cause confusion. The blind reader is presented with the end results of the graph before he or she finds the beginning of the graph.

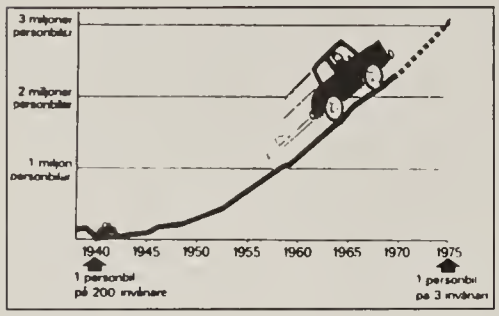


Details that make it difficult to trace a line should be removed. The grid of a printed graph, transferred to the relief display, can be more of a deterrent than a help to the reader, especially in one-elevation reliefs. The grids in the following graphs can be left out if the coordinating lines are clearly marked at the same intervals as on the printed grids (see "Grids and Guidelines," this chapter, for more on this).



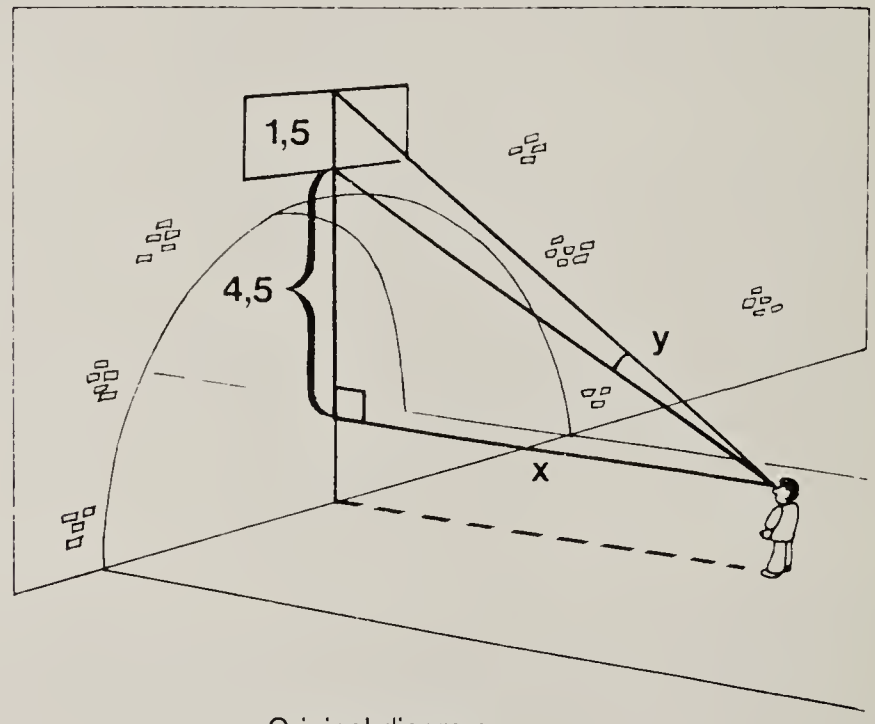


Areas that are unnecessary and do not add to the information in the diagram should be removed. The text preceding the diagram shown below informed the reader that the diagram shows air distances. Therefore, the plane is not necessary and should be removed. It would be easier to read the diagram if the routes were numbered and the distances stated in a key.



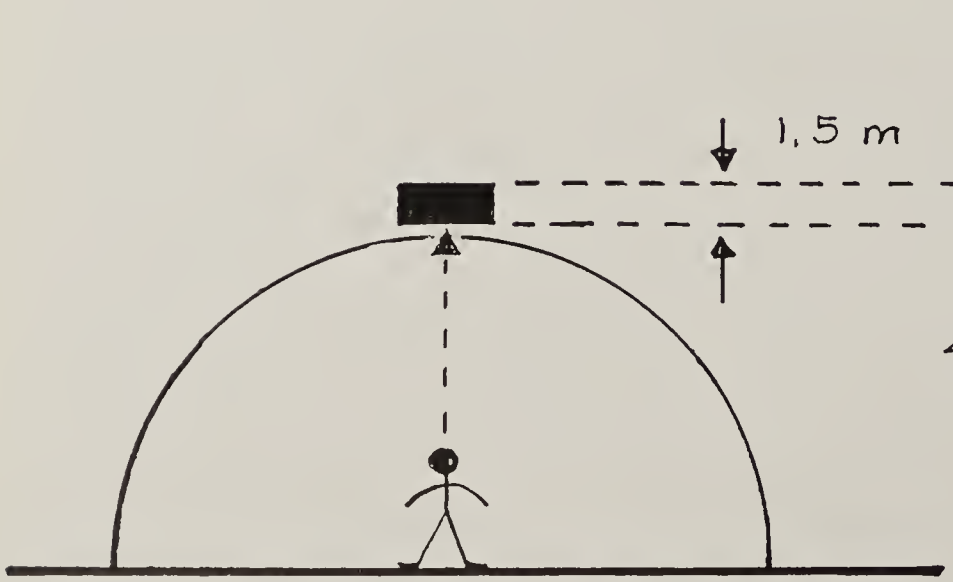
The graph on the left shows the number of cars per person in the population: in 1940, 1 car for every 200 inhabitants, and in 1975, 1 car for every 3 inhabitants. The cars shown in the picture were already described in the book text and would not add new information to the diagram. Also, cars pictured in two different scales could be confusing to the reader. The cars would make line tracing difficult. They should therefore not be included in the diagram.

Diagrams based on a perspective drawing, such as the one shown below, should be redrawn. The relief illustration should present a front, side, and top (overhead) view of the textbook material.

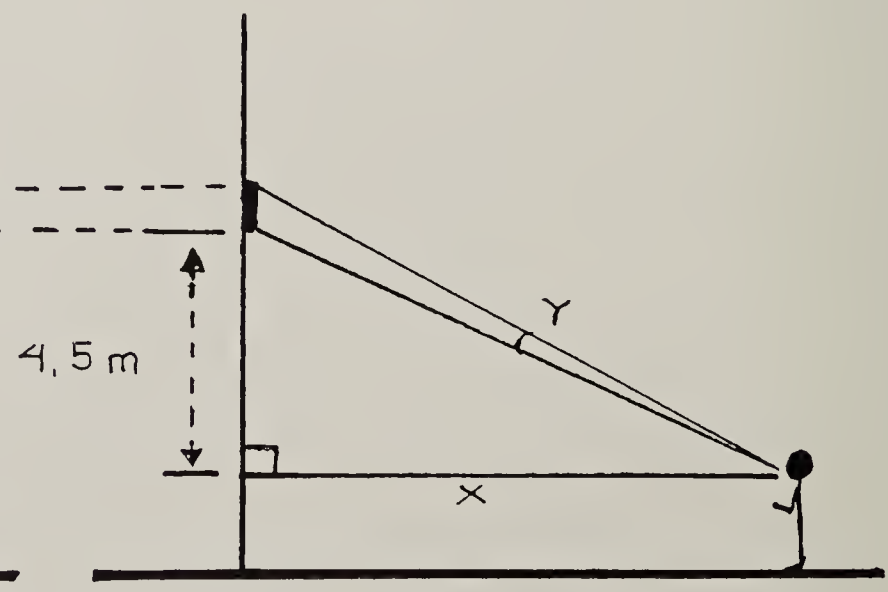


Original diagram.

The following is a sketch for the master maker:



Front view.



Side view.

An illustration of the overhead view of the original diagram is not necessary. The text accompanying the diagram reads:

> A man is about to walk under a viaduct. Over the entrance to the viaduct is a sign, 1.5 meters in height, placed 4.5 meters above the man's line of vision. The man sees the sign at the visual angle Y when he is X meters from the viaduct.
>
> 1. Show that Y = arctangent (6/X) - arctangent (4.5/X).
> 2. How far away from the viaduct is the sign visible at the greatest possible angle of vision? Solve the problem numerically by calculating Y for appropriately selected values of X.

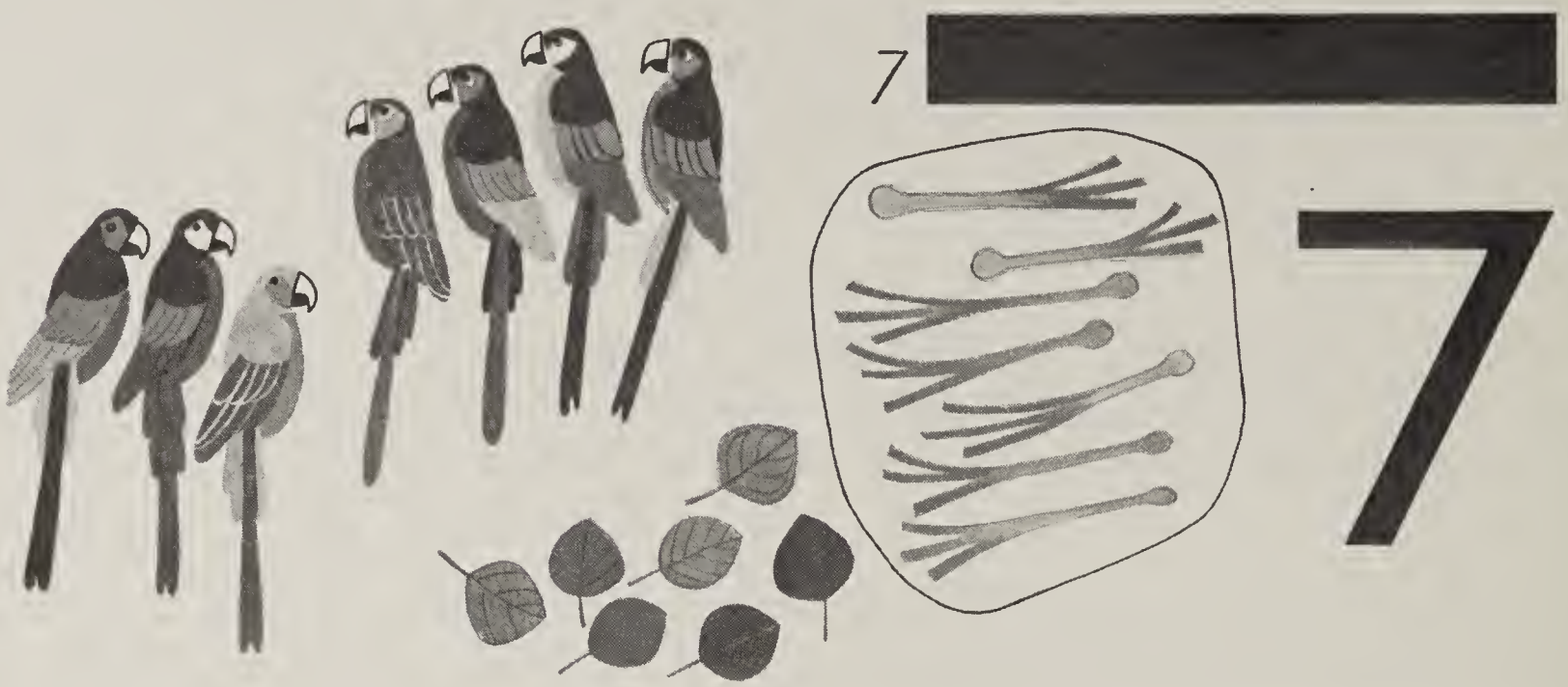
Although the text may be sufficient to solve this problem, the diagram organizes the information and should be of help to the reader.

MATHEMATICS FOR BEGINNERS

The number of written digits in a sighted child's first arithmetic book is few, but the pictures—of everything from elephants to shoes—are many! Transposing these books into relief material for the blind child can have its problems.

The first stumbling block is making a literal translation of the printed illustrations into relief displays. Think before you follow this line of action. At times, it is tempting to give the visually impaired reader in an integrated class the same material as his or her sighted classmates. Run your fingers over the printed diagram and try to feel mentally what your fingers would encounter if the diagram were in relief. This activity may sound strange to you, yet often it gives you a good idea of what to expect from a direct translation.

Very young students are apt to have a limited vocabulary. Consequently, the use of braille words in a first arithmetic book for young blind readers is restricted, as is the use of complicated forms or shapes. Beginning readers are learning to read two-dimensional illustrations and understand their meaning. Developing this knowledge takes time. Illustrations made by a master maker with years of seeing experience may not fall within the limits of the young blind child's comprehension. The examples that follow show what I mean.

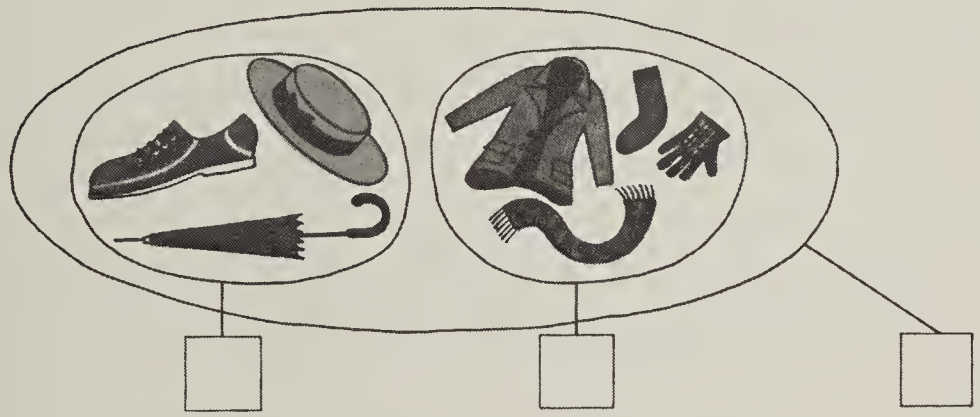


Above: A textbook illustration from the first-grade mathematics book, *Matematik A, Grundbok* (Rosenberg, Lindström, Natt Och Dag, & Högberg, 1972).

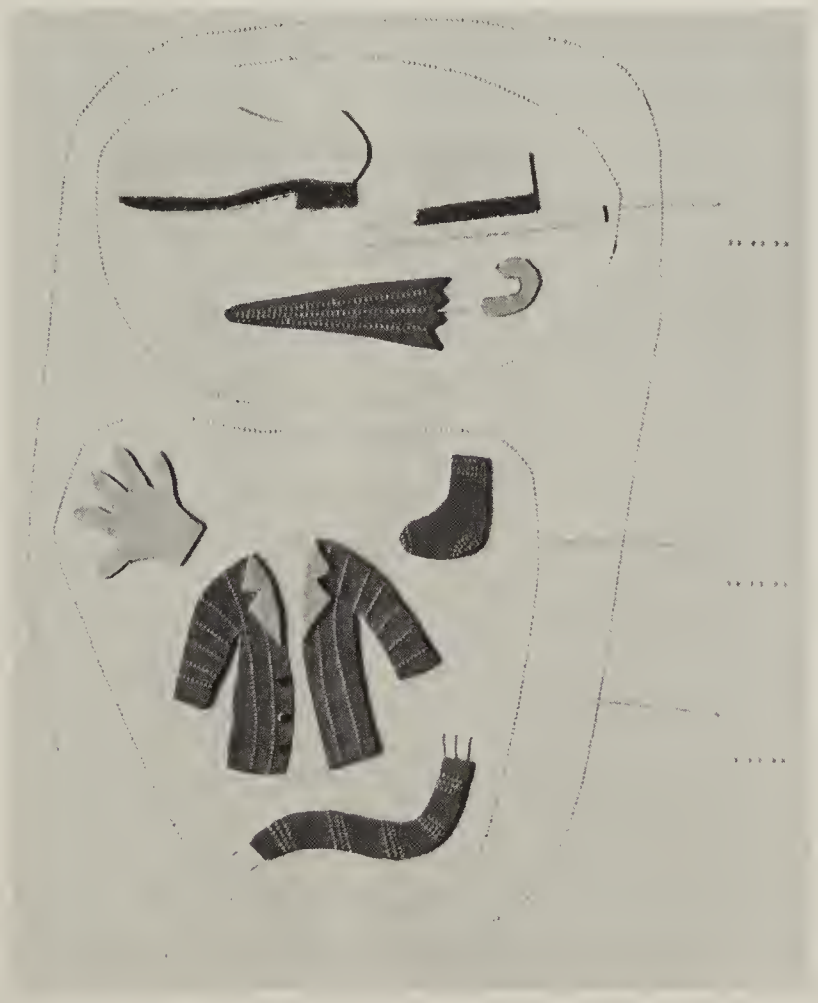
Right: A relief display made for *Matematik A, Grundbok*. The subject is the number 7.

Compare the original illustration from a first-grade mathematics book and the relief display shown on the previous page. The only difference is a more ordered layout in the relief version. Someone will have to tell the blind child that there are parrots, leaves, and green onions because these are not forms the child is apt to recognize without referring to a three-dimensional object--if he or she can recognize them at all. The only thing the child may understand is that there are seven of something here. And the child will not recognize that the seven "somethings" are the same object when he or she feels the parrots—four facing left and three facing right. These forms do not feel like and therefore become two different objects.

In the next example, below, the relief display follows the printed illustration closely. The original layout has been changed to accommodate the size of the braille book page.



A textbook illustration of a problem in first-grade mathematics showing the addition of 3 and 4, from *Matematik A, Grundbok.*



A relief display of the problem.

Although young blind readers may be familiar with the three-dimensional objects portrayed, they will not be able to recognize these relief pictures by themselves. Nor can they gain clues from the different materials used in the individual objects, since the page they feel is a plastic copy of the paper-on-paper master. The confusion may also be increased by the varying scale of the objects pictured on the page. But this is not the point; recognition of objects is not the purpose of this exercise. This is a mathematical problem—the addition of 3 and 4. The variety of the objects portrayed distracts readers and slows down their ability to answer the problem. The two examples of relief displays shown so far would have been better for visually impaired readers if they had been made using coded symbols.

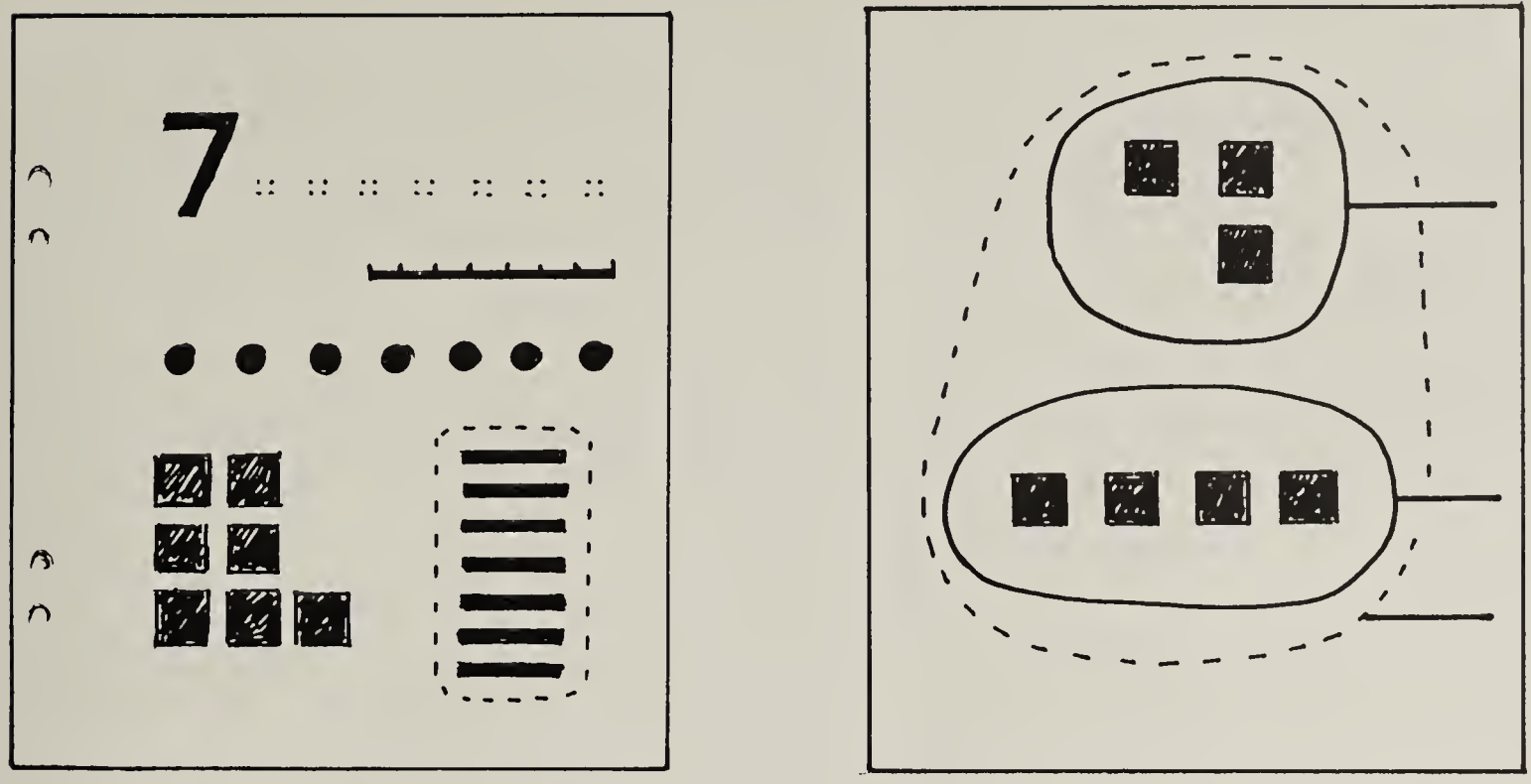
Coded Symbols

The forms in printed displays are replaced in relief displays by simple shapes, circles, squares, and triangles or braille symbols for easier readability. These substitute forms are often called coded symbols and are used when it is not necessary to maintain original shapes and textures to convey the illustrated message.

This technique is particularly adaptable to relief displays of mathematics for beginners, but it can be used in all types of relief displays that are transposed from printed material. It may be necessary to inform the reader that this substitution has taken place when using coded symbols, especially if the symbols are used in place of color or shading in more complicated diagrams. Sketches of the relief displays illustrated earlier under the section "Mathematics for Beginners" made with coded symbols are shown on the next page.

The sketch of the display of parrots, leaves, and green onions has a row of braille sevens on the master. The bar is 7 cm long (the length to be measured by the children) and corresponds to the thick black horizontal line in the original illustration. The large number 7, followed by the braille numbers, was moved to the left so that it became the first object that the child feels when he or she scans the page.

Coded symbols are used in counting exercises when counting, rather than the recognition of different elements within the



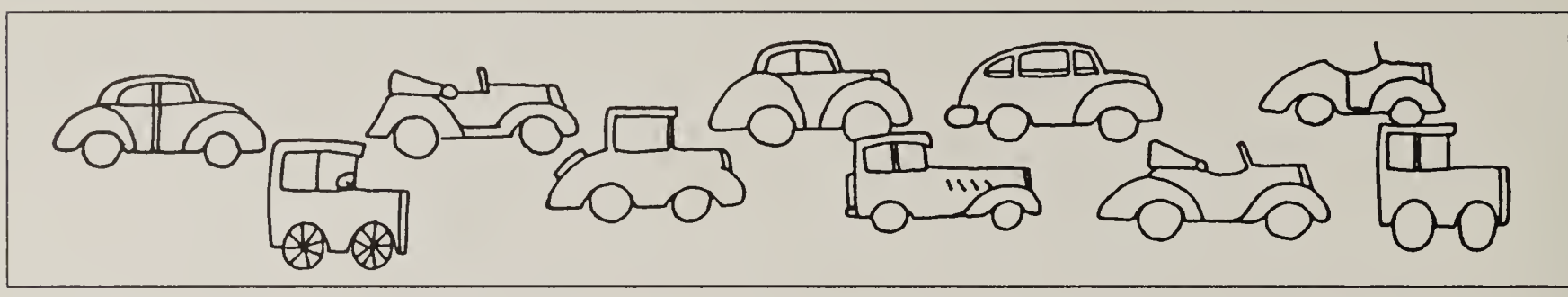
Sketches of relief displays for elementary mathematics that use coded symbols.

layout, is the object of the problem. They are therefore used in the other sketch shown here, which relates to the display shown earlier for the addition of 3 and 4. Answers should be made on a separate page.

Irregular and Orderly Layouts

Many schoolbooks for beginners have cluttered illustrations that readers are supposed to use to solve some type of problem. For sighted children with the ability to scan a picture at a glance and hop over the unimportant details, this is not a problem but a challenge. For blind children, a literal translation from this type of inkprint illustration to a relief display is a disaster. The confusion of shapes in an unorderly layout is difficult to follow, especially if the layout concerns an arithmetic problem.

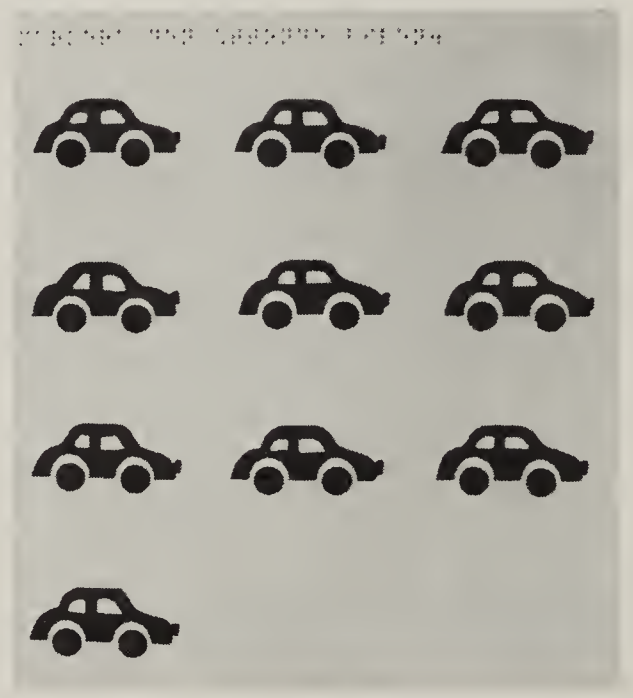
The reader can follow the irregular arrangement of shapes in the sketch of the display of parrots, leaves, and green onions shown above because of the amount of space surrounding each group of seven forms and the compactness of these forms within each group (as opposed to the free-form layout of the original illustration). In the illustration of cars shown on the next page, the placement of the cars makes it difficult to count their number. (There is no reference line to help the reader keep track of them either.) In addition, the cars have different shapes, which can be distracting to the reader trying to count them. On the paper-on-paper master made for this



The textbook illustration for an exercise called "paint the eighth car."

illustration, shown below, the reader was asked to mark the eighth car. The consistency of the form used for the cars in the display and the spacing between the cars make counting easier for the blind reader.

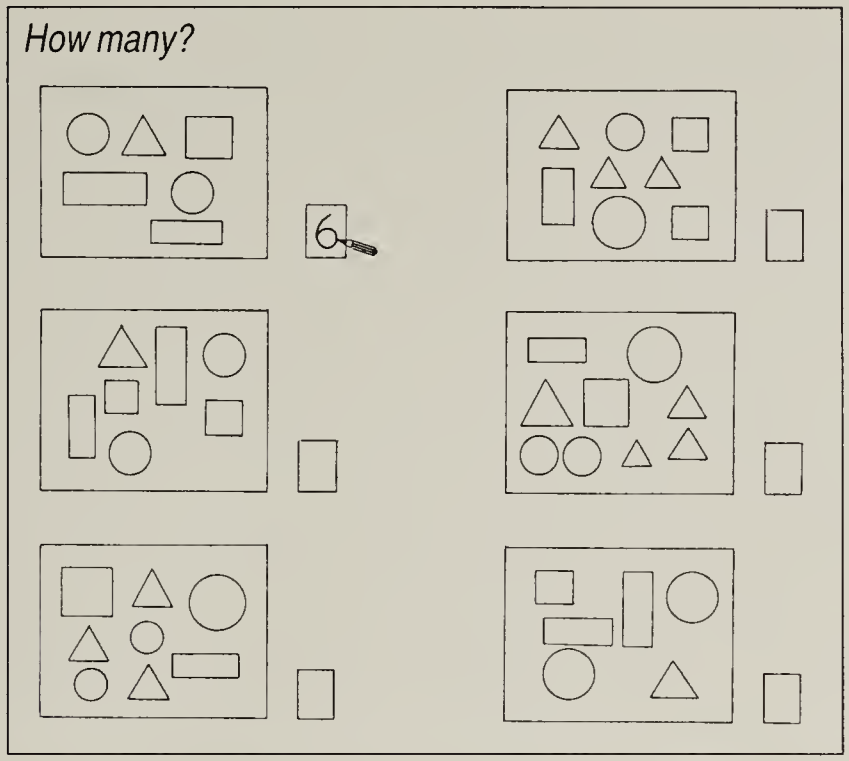
Coded symbols would have been used for this display if the teacher had not requested cars. Apparently, model cars were used in the integrated classroom discussions. The decision whether to make textbook material more suitable to the needs of the blind child or to make the relief material as closely related as possible to material used by the sighted children in a class is often difficult and varies from problem to problem. In this case, the teacher decided it was important that the blind child not feel different from the rest of the class.



The paper-on-paper master.

Contact with teachers who will be using your material is invaluable. Because they know their students' needs, they can help you with many of your problems. Such contacts may determine whether your material will be used in the right way or not, or even whether it will be used at all.

The groupings of shapes in the following textbook illustration (from Rosenberg, Lindström, Natt Och Dag, & Högberg, 1972) should be reorganized in the relief display for quicker reader comprehension. There are several factors to consider.



Once again, you should know how the exercise is to be used. Is the student asked to do more than add the number of shapes within each grouping—for example, to add the numbers of squares, triangles, and circles?

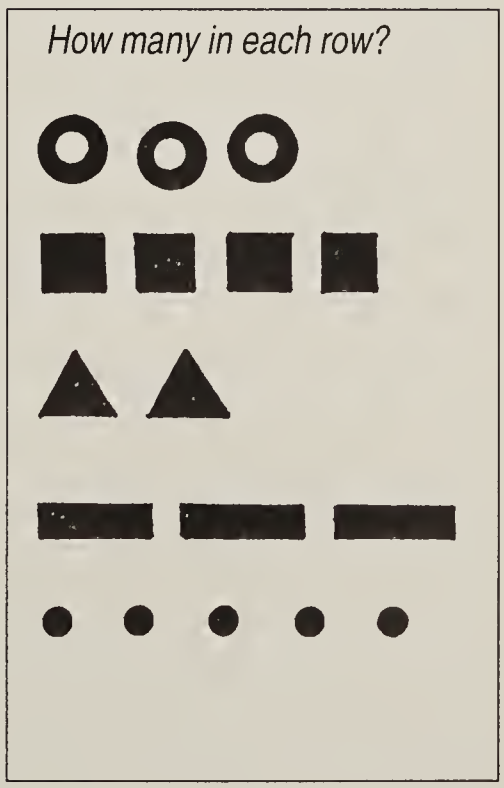
If only one answer is required, for example, the total number of items in a group, use only one shape to a group and place the shapes in an ordered layout:

6 = ○○○ ○○○ or ○○○○○○

If several answers are required, placing the shapes in a line makes it easier for the reader quickly to recognize the different shapes and the number of each type of shape involved. The difference between shapes should be so obvious that there is no chance for confusion (see "Point Symbols," Chapter 6).

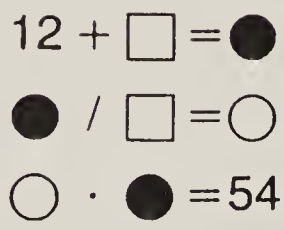
6 = ○ △ □ ▭ ○ ▭

This type of exercise could be done on a magnetic board, on pop sheets, or on microcapsule paper (see "Displays with Movable Parts" and "Answer Cards and Pop Sheets," Chapter 2). The illustration shown at the right uses shapes that are a suitable size for the exercise. For easy handling, loose shapes used on a magnetic board should be larger.

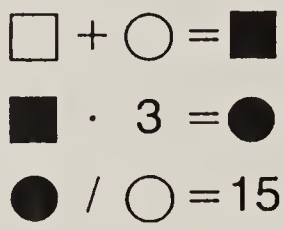


The reader should be asked to write his or her answers on a separate sheet of paper. It is difficult to adjust an exercise sheet in a braillewriter so that the answer and the problem are on the same line.

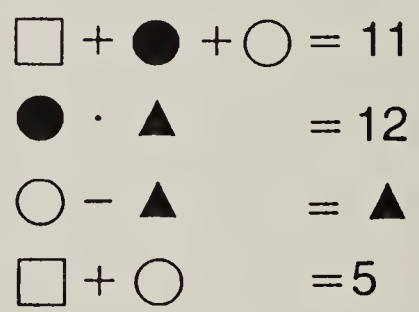
At first glance, the next exercise shown below looks as if it were a continuation of the one on the previous page, but the use of geometric figures is the only thing the exercises have in common. The symbols used here are coded symbols in an exercise for a class that can already add, subtract, multiply, and divide. Each type of symbol represents a number. The symbols do not represent the same number from one problem to the next. For instance, here is the solution to problem 1: 12 + 6 = 18, 18 ÷ 6 = 3, 3 x 18 = 54.



1.



2.



3.

The Use of Money on a Master

Addition and subtraction problems for beginners often deal with money. For example, they may ask how many cents are in a nickel or a dime. Real coins can be used on a built-up master that is to be reproduced in a vacuum-forming machine. They will give children additional training in coin recognition, a better understanding of the three-dimensional object and of a picture of that object, and, perhaps, a better concept of the size relationships among coins.

This type of relief plastic sheet could be reversed so that the child could use actual coins as puzzle pieces, fitting them into the indented areas on the sheet—another way to learn addition and subtraction through play (for similar puzzle pages, see "Displays with Movable Parts," Chapter 2). Be sure that the coins used on the master have a sharp relief pattern so the pattern can be felt on the plastic copy.

Pop Sheets for Elementary Arithmetic

The press-down pop-up technique for addition and subtraction is used with pop sheets (an alternative to the number line,

discussed later). These sheets are vacuum-formed plastic copies of a built-up master (see "Answer Cards and Pop Sheets," Chapter 2). They are covered with relief dots that can be pressed down on one side of the sheet and popped up again from the reverse side of the sheet. One sheet 8.27 in. by 11.69 in. (21cm by 29.7 cm) consists of ten numbered rows of ten dots each. Several sheets can be taped together to extend the rows of dots. These sheets can be used over and over again.

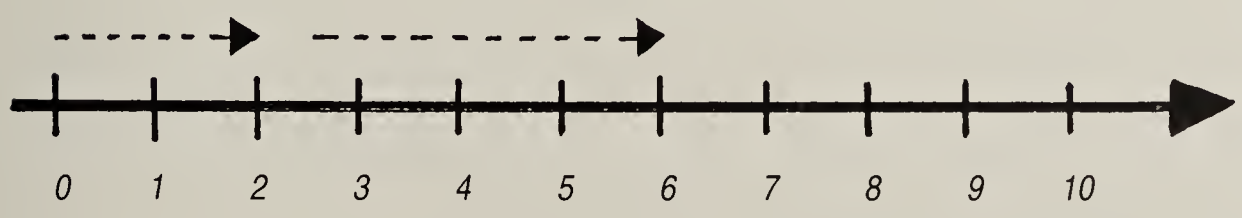
The size of the dot can vary according to the ease with which the dot can be pressed down and its ability to stay depressed until it is popped up. Sizes from .28 in. to .47 in. (7 mm to 12 mm) have proved suitable. The size can also depend on the motor coordination and ability of the reader.

Addition

Here is how addition can be done with pop sheets. Press down the amount of dots that make up the first number. Continue along the same row, pressing down the amount of dots that make up the second number, the third number, and so on. The sum of the problem is the amount of depressed dots in the row. For example, to solve 2 + 4 = 6:

third step, the sum of the depressed dots is the answer to the problem

Pressing down dots stimulates the blind reader's interest. It improves coordination and the ability to control movements and, above all, it is more fun to do than counting crossbars on a number line.



A number line.

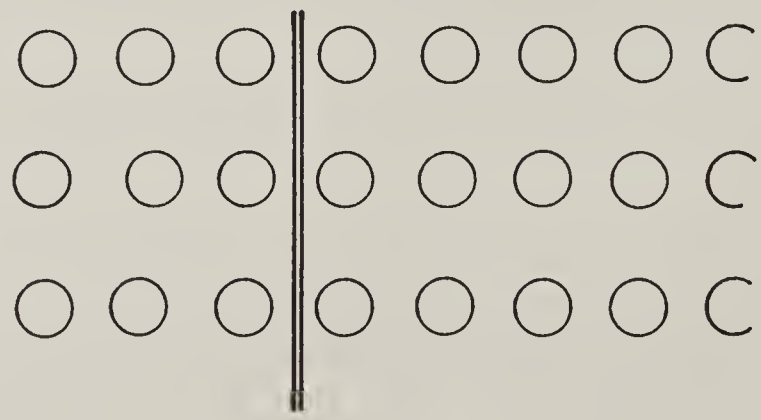
Subtraction

For subtraction, decide which number in the problem is the largest. Count the dots along one row until this number is

reached. Press down this dot. From and including this dot, count back toward the first dot in the row, pressing down the number of dots that are to be subtracted from the larger number. The number of unpressed dots that is left at the beginning of the row is the answer to the problem. For example, to solve 5 - 3 = 2:

Teaching mathematical techniques is not the purpose of this handbook. However, it would not be reasonable to expect you, as a producer, to use this pop system for beginning arithmetic students without the knowledge of how to use pop sheets.

It may be advantageous to have a dividing line on a pop sheet if a page of problems deals with one number in particular, for example, number 3: 3 + 6, 3 + 2, 3 + 5 + 2, and so forth. A dividing line can be made by stretching a rubber band over the master before vacuum-forming the plastic sheets. Check that the band is rubber, not plastic. A plastic band may not be heat resistant. If it melts in the vacuum-forming process, it may destroy the original master for future use. A thin strip of tape can also be stuck across the plastic page. This tape is easily removable if the plastic sheet is to be used for other purposes.



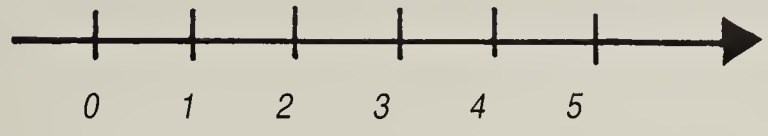
A dividing line for a pop sheet.

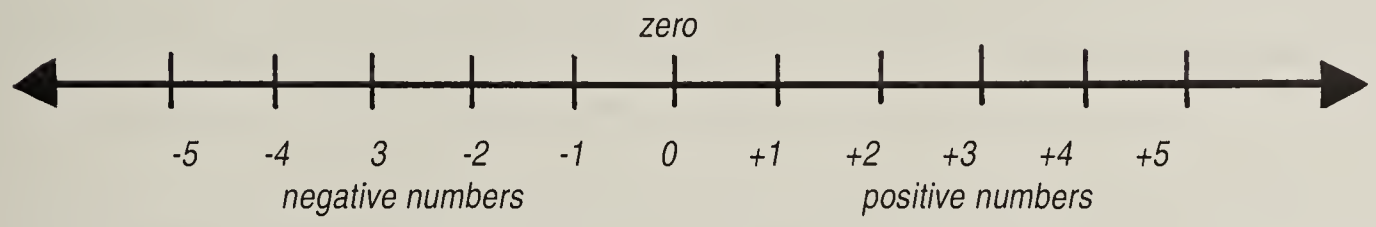
NUMBER LINES

The purpose of a number line is to teach relationships among numbers. The length of a number line is not standard or definite; it can vary according to the use of the line. The divisions of the line correspond to actual numbers progressing

in numerical order in a positive or negative direction from zero. The distance between the numbers on a line is most often the same. These distances, however, do not necessarily relate to any standard unit of measurement, such as inches or millimeters.

Number lines can be presented horizontally or vertically:

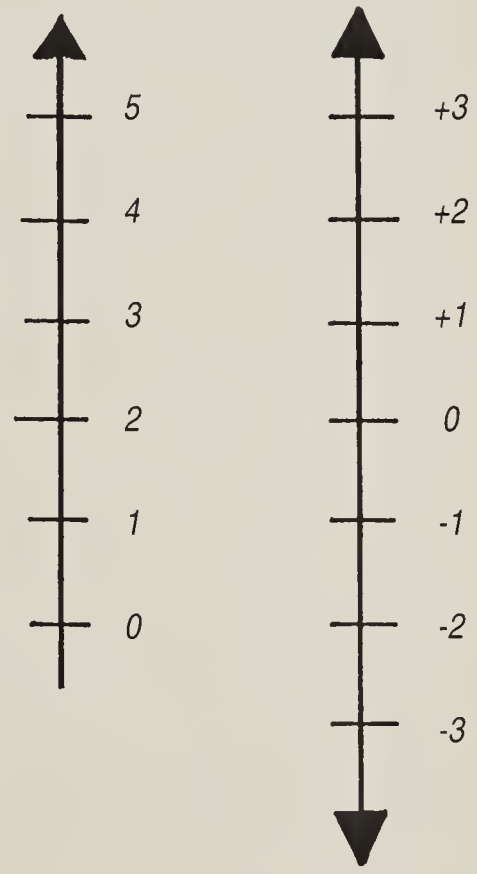


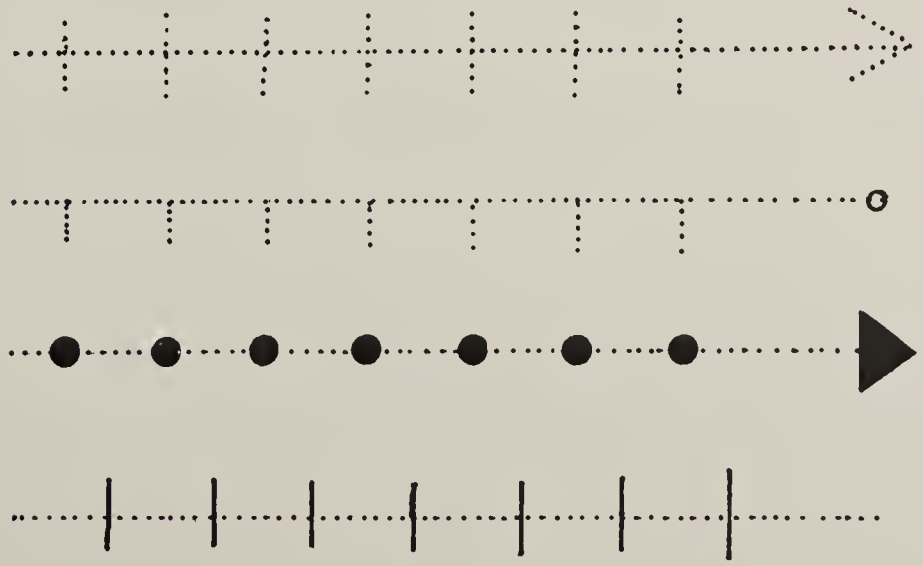


On a vertical line, the smallest number should be closest to the bottom of the page. The numbers increase as they progress upward.

The following are suggestions for making number lines:

- The relief of the divisions of the line should be made as high as or higher than the line itself. Divisions may be made in the same texture or material as the line or from a different material.
- Number lines can be made on a built-up master or microcapsule paper using the embossed technique. The lines shown below were made with a variety of tools and methods.





Fine-line spur wheel.

Fine-line spur wheel; dot made with correction tong.

Fine-line spur wheel; dots and arrowhead cut or punched from cardboard.

Divisions made of string or heavy thread glued over the line.

String glued to the line to mark a particular area.

Line and divisions made of string; symbolized arrowhead is a knot in the string.

Divisions of the line made on one side only.

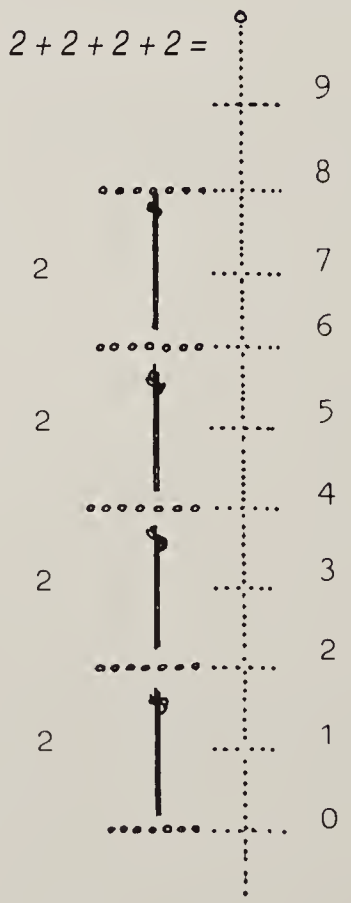
Line and divisions made of string; heavy paper added to the line to mark a particular area; string division lines are glued on top of the heavy paper.

Line and divisions made with correction tongs.

Line made with correction tongs; divisions made with string.

Line made by a spur wheel.

Fine spur wheel
Correction tongs
String; knot indicates direction



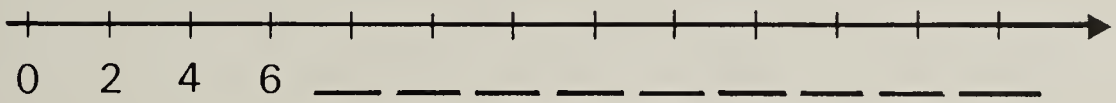
Addition (*reduced from actual size*)

Subtraction (*reduced from actual size*)

The following are typical number-line problems:

- Which numbers are missing from these number lines?

13



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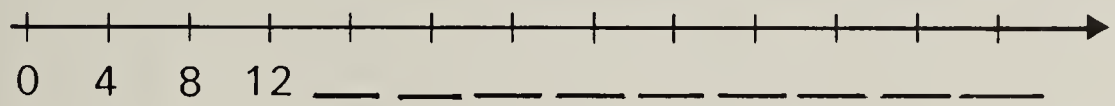

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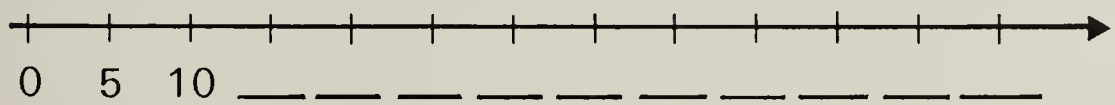
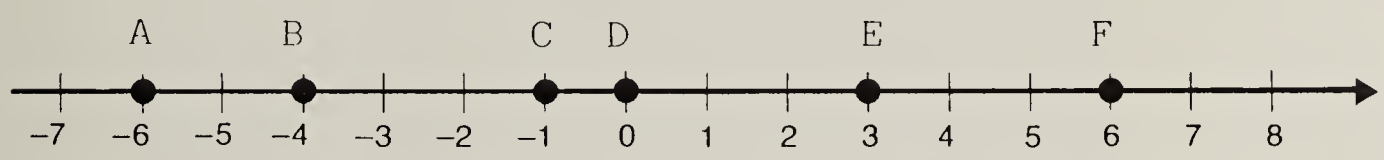
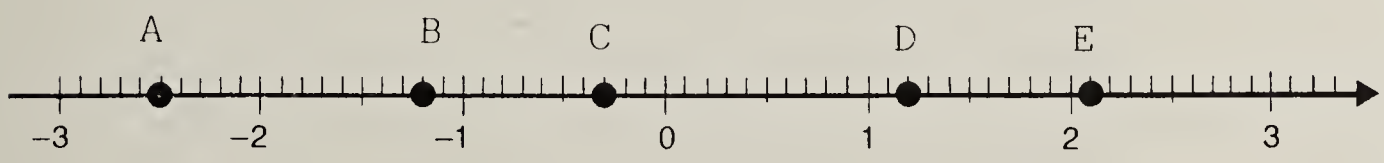


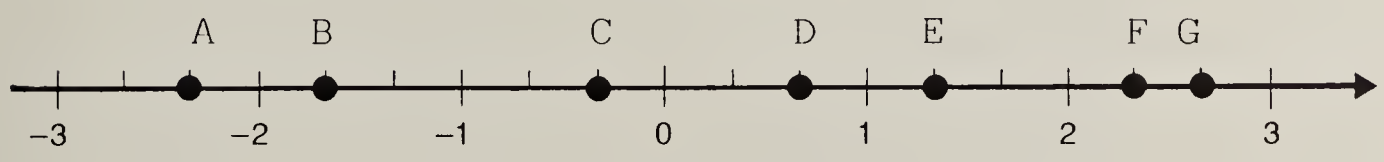
- Which of the numbers marked by dots are positive? Negative?



- Which decimals are marked by the dots?

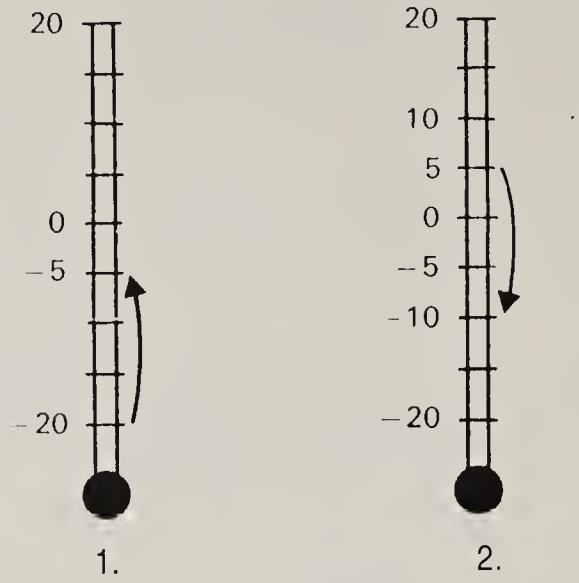


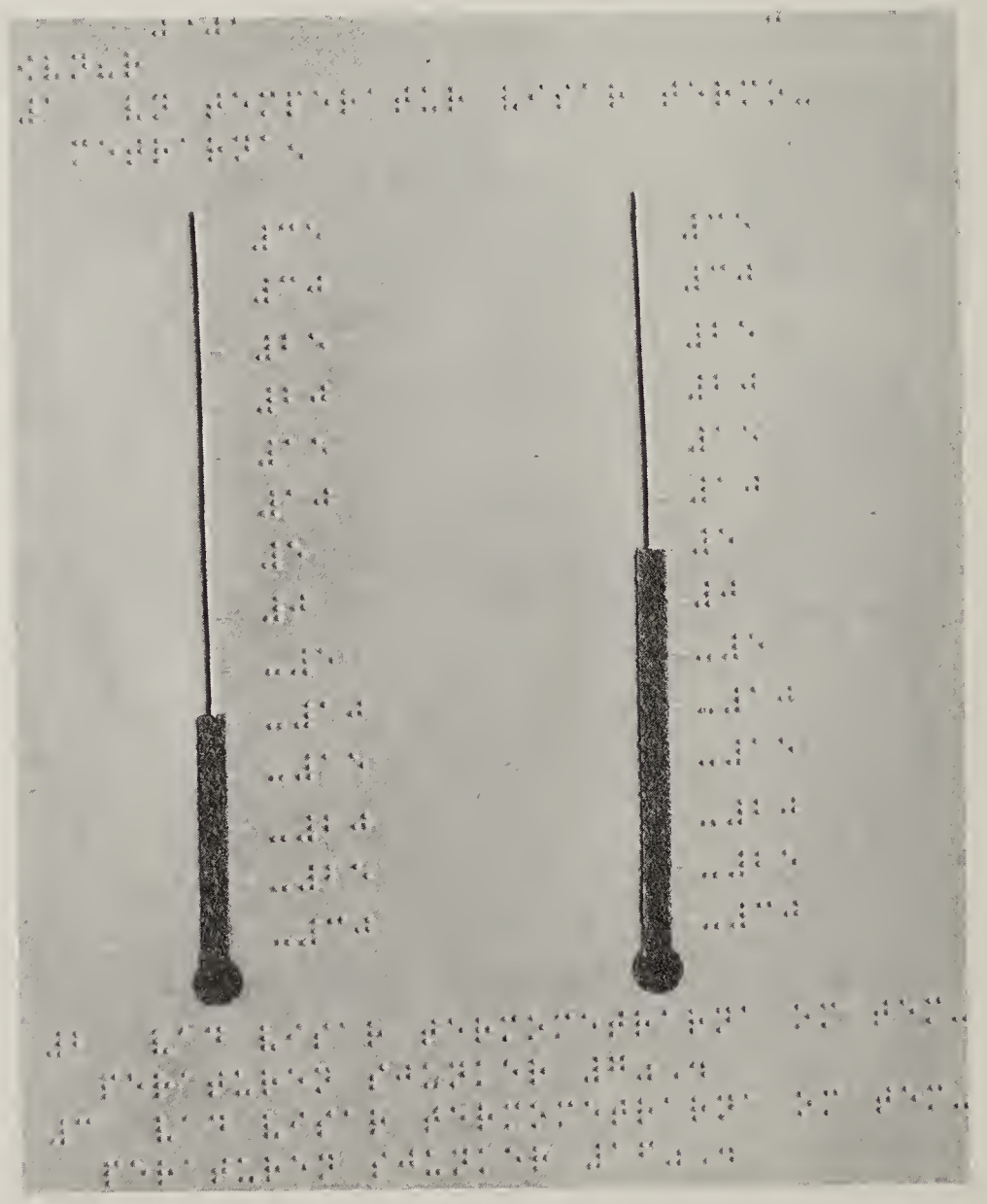
- Which fractions are marked by the dots?



A useful application of number lines is in thermometers that show temperature scales. Thermometers are especially effective in illustrating problems involving negative numbers, such as those shown on the following page.

1. How much has the temperature changed from -20° to -5°?
2. How many degrees has the temperature changed from 5° to -10°?

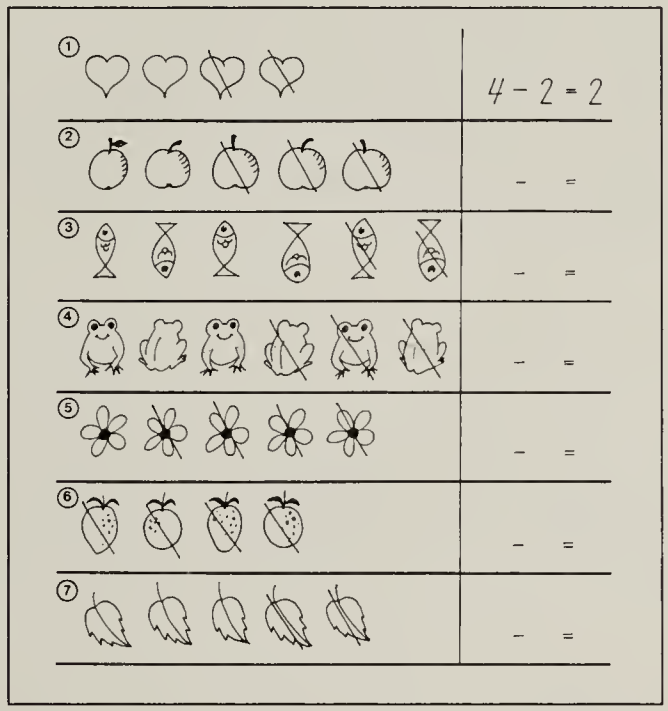




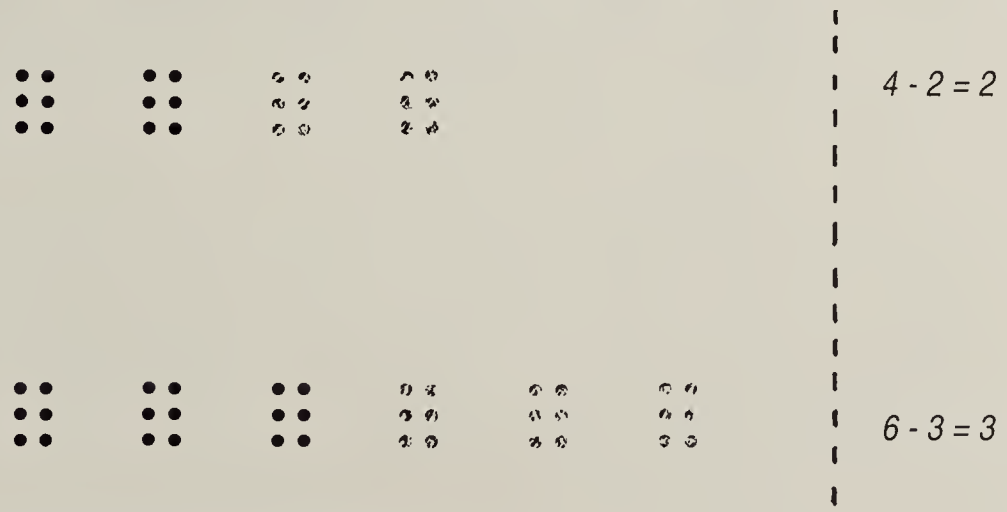
Thermometers can be made from various materials. In the illustration here, they are made from sandpaper and coarse thread.

ADDITION AND SUBTRACTION WITH BRAILLE CELLS

Subtraction with what are called shadow figures has a twofold purpose: to present simple subtraction graphically to beginning readers and to receive graphic evidence from these readers that they understand the problems. An example of the system is shown here, with the type of illustration often found in first-grade arithmetic books and a relief display of part of the illustration. The original illustration:



Problems 1 and 4 made into a relief display on a braillewriter:



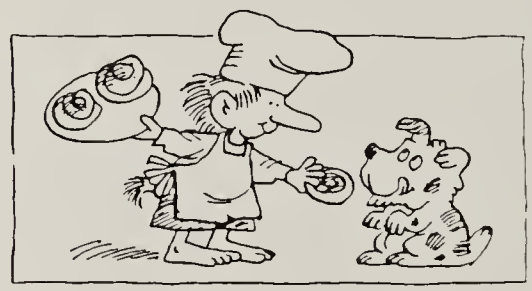
The method used is as follows:

- Print as many braille cells as there are units in the largest number of the problem.
- Starting at the right-hand end of the line and working backwards, lightly press down as many braille cells as are to be subtracted from the larger number. These "flattened"

braille cells become shadow figures that can still be felt but are not as prominent as the unflattened cells.

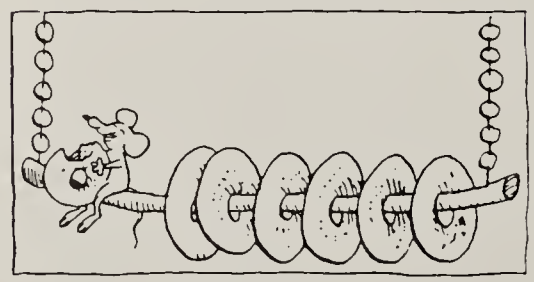
- The reader feels the number of digits as a whole, counts the shadow figures, and becomes aware that the remaining cells make up the answer. This type of presentation makes it easy for the student to answer directly on the braille paper, opposite the problem and on the other side of the embossed line.
- Use only the 6-dot braille cell to present the problem.
- Leave one space between each braille cell and two empty lines between each problem line.
- Before making shadow-figure subtraction displays, check with the teacher that the student can feel and understand these figures. Some students may have difficulty in feeling the low relief.

The textbook illustration from the mathematics for beginners book shown here, *Andra Räkne Boken* (Olstorpe & Skoogh, 1986), could also be translated into shadow-figure braille, and for young students, each problem could be accompanied by a short tale.



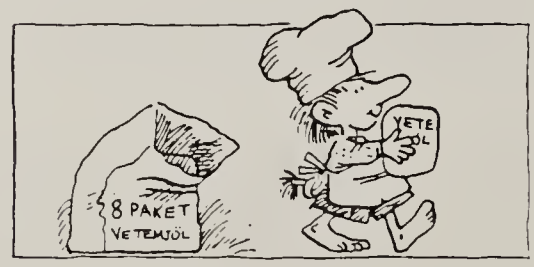
3 - 1 = ___

9 - 1 = ___



7 - 1 = ___

1 - 1 = ___



8 - 1 = ___

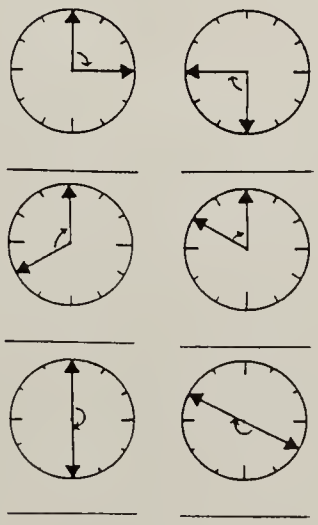
6 - 1 = ___

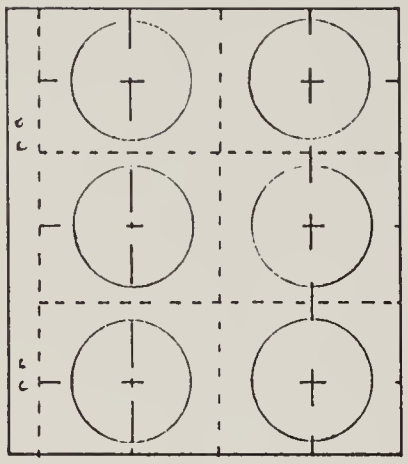
Addition with braille cells is another useful technique.

In examples such as the ones shown here, from *Visst Kan Jag Räkna!* (Ericson & Fellenius, 1980), leave one space between each braille cell, three spaces between number groups on the same line, and two empty lines between each problem line.

CLOCKS

Teachers often request clock displays—and no two clocks ever show the same time! To save your own time, try to mass-produce clock displays that can be used for any clock problem.





Types of Relief Clock Displays

Clocks without Hands

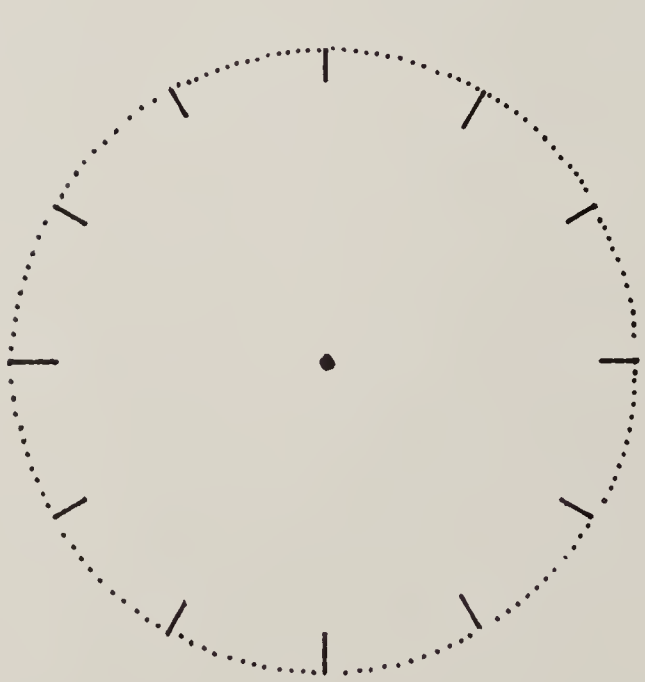
Several clock faces can be made on one master from which plastic copies are produced. Six large-size faces fit on a standard sheet of A4F braille paper, 10.25 in. by 11.75 in. (26 cm by 30 cm).

The outside diameter of the clock face is 3.12 in.(8 cm). The page margin is 7.8 in. (20 cm). These faces can be made with numbers or with symbols indicating these numbers.

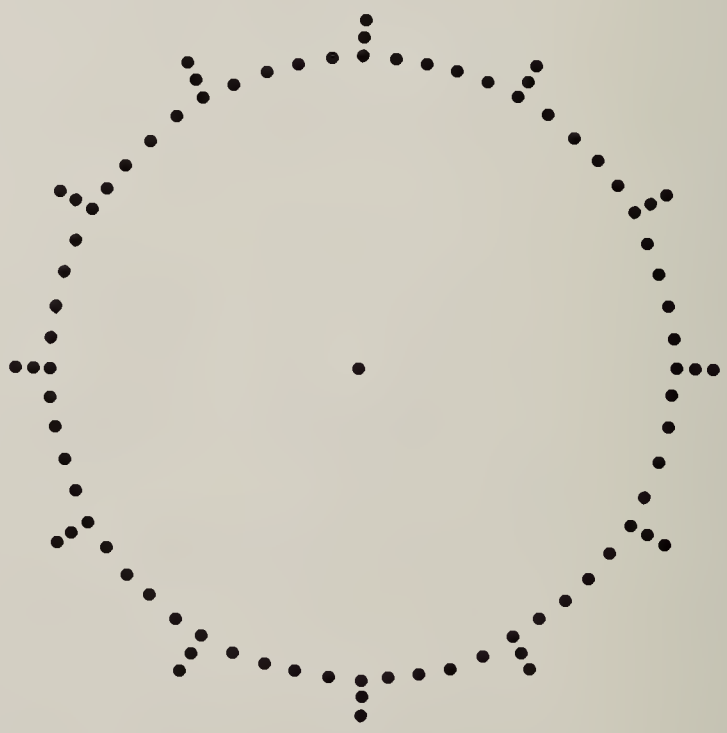
Teachers can add hands where they want them by using a spur wheel on the reverse side of the plastic sheet, by gluing cardboard or string hands on the front side of the sheet, or by sticking tape hands to the sheet.

Faces can be made

- By embossing circles on braille paper with an embossing compass (as in example A shown below) or with correction tongs (as in example B). The lines in example A marking where the clock's numerals would appear are made by embossing the paper with the end of a screwdriver.



A.



B.

- By forming circles of preglued string (see "String and Thread," Chapter 2) or by cutting narrow cardboard rings that are to

be glued to paper backgrounds. These displays can be used as they are, or they can be mass-produced in a vacuum-forming machine. Numbers are often indicated by dots punched from cardboard or leather and glued to the clock face.

- From an original drawing for a microcapsule paper relief display. The teacher can add hands (as mentioned for plastic clock displays), or the hands can be drawn on the relief display with a carbon pencil or pen and the face plus hands reswelled in an infrared heater (see "Microcapsule Paper," Chapter 2).

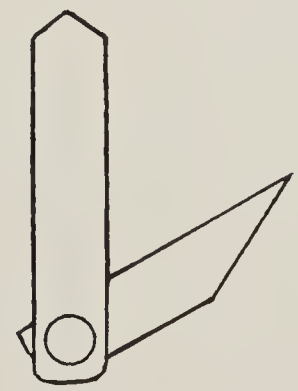
All clock faces should be made with a center dot. This facilitates placement of the hands in the correct position.

Clocks with Movable Hands

Often you, the tactile graphics producer, may want to add movable hands to a clock face before sending it to the student or teacher. The hands should be made to withstand a great deal of handling. Lightweight but firm plastic makes excellent hands, as does thin, sturdy cardboard. Before you attach the hands, you need to make a center hole, and it may be necessary to reinforce the back of the clock face with tape or by gluing a thin layer of paper over the area surrounding the hole. Using a brass paper fastener to attach the hands allows them to be moved separately.

The size of the hands is decided by the size of the clock face. Hands about .3 in. (8 mm) wide work well on a clock face that is about 3.12 in.(8 cm) in diameter. The difference between the minute hand and the hour hand should be easily felt. Be sure to place the minute hand over the hour hand before fastening the hands in place.

Digital watches and clocks—timepieces with the numbers displayed directly in digits in visual readouts—are not used by blind persons, unless they are "talking" devices that can announce the time. Textbook problems showing digital watches or clocks should therefore be transposed when made into relief displays. They should be made as other clock displays, with movable hands. Write the desired time in braille and, in the text, ask the student to arrange the hands in their proper positions.



Clock hands held in place by a paper fastener.

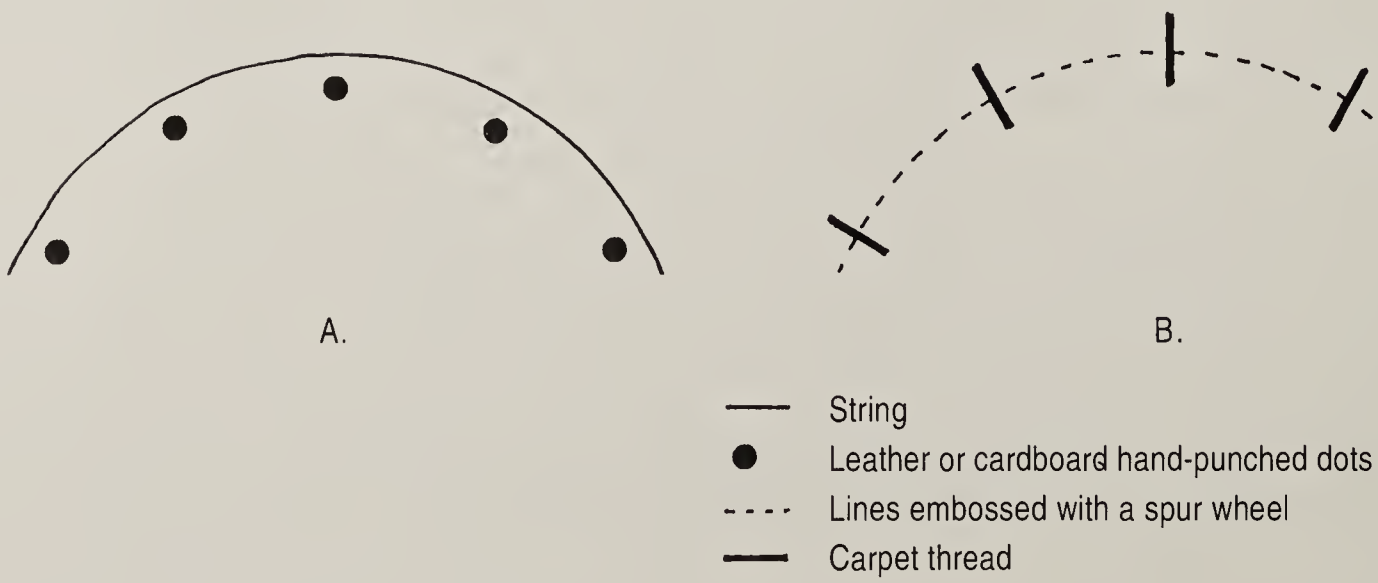
A clock with permanently placed hands.

Clocks with hands that are permanently placed are made to solve particular problems or questions. The hands are glued onto or embossed into the master or are a part of a microcapsule paper display. Such a display may be necessary if the blind student is working unaided with an exercise book or a workbook or is taking an examination. The clock shown above has hands made of thin string.

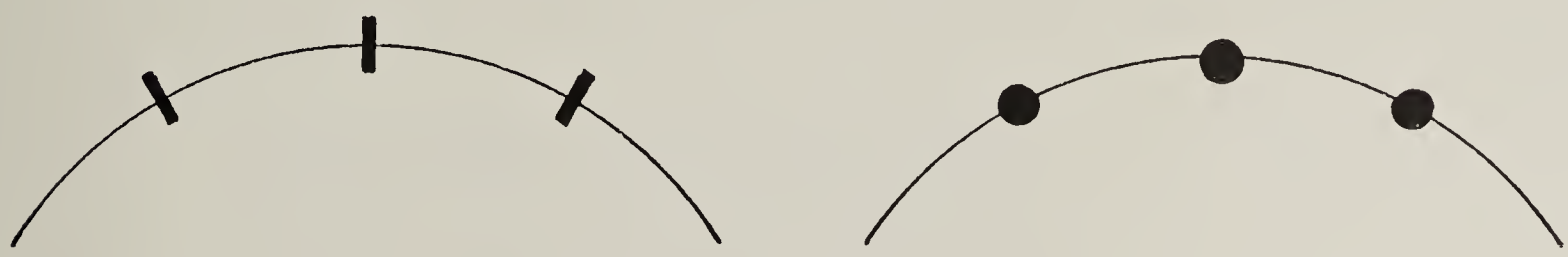
Clock Faces

Minute Markings

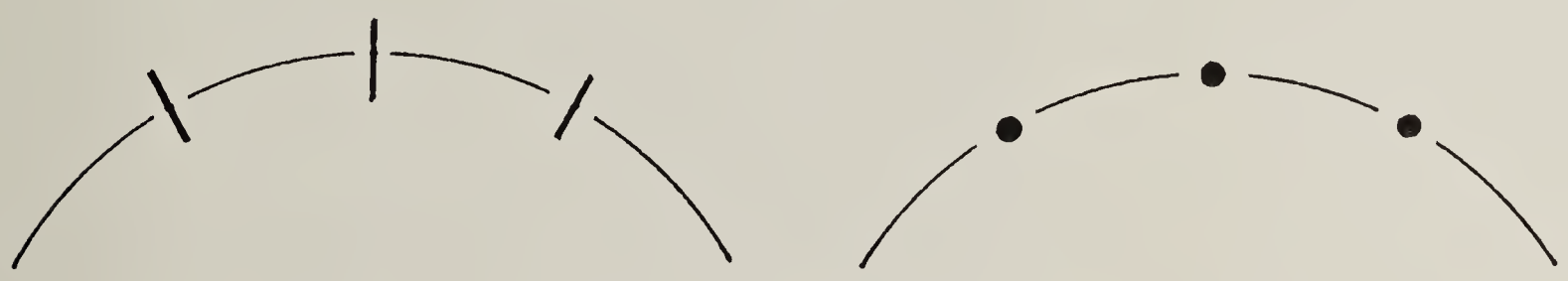
The five-minute intervals that appear on a clock face should be clearly marked, so that it is obvious that they are more important than the relief edge of the clock face. Space the marks 1/8 in. (3 mm) from the circumference of the clock (see A) or directly across the circumference line of the clock (see B).



Five-minute markings made on a built-up master should be more elevated than the circumference line of the clock face. On a microcapsule paper relief, these markings should be thicker than the circumference line (see C), or the circumference line should stop before each five-minute mark (see D). This will emphasize the marks in a one-elevation relief.



C.



D.

One-minute intervals can be indicated by shorter lines (see E) or by smaller dots (see F) or by a combination of lines and dots.

E.

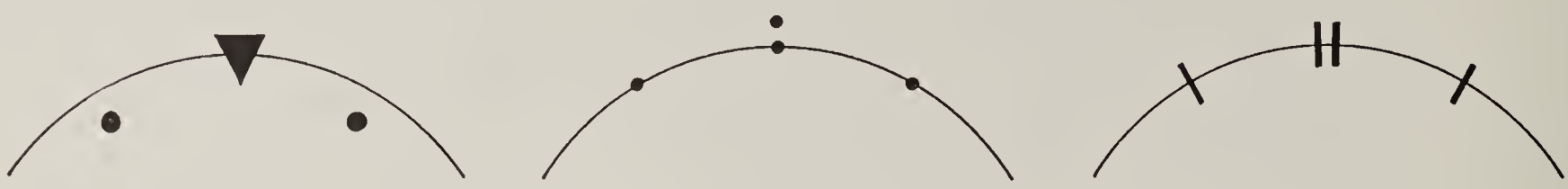
F.

The size clock face referred to earlier — 3.12 in. (8 cm) — is easier to read when the circumference line is taken away. On larger clock faces with a diameter of 4 in. to 4 3/4 in. (10 to 12 cm), the circumference line helps hold the elements of the clock together.

The addition of one-minute marks depends on both the problems for which the clock is used and the ability of the reader. Clocks requiring one-minute or one-second marks are usually much larger than those showing only five-minute intervals.

Numerals on the Clock Face

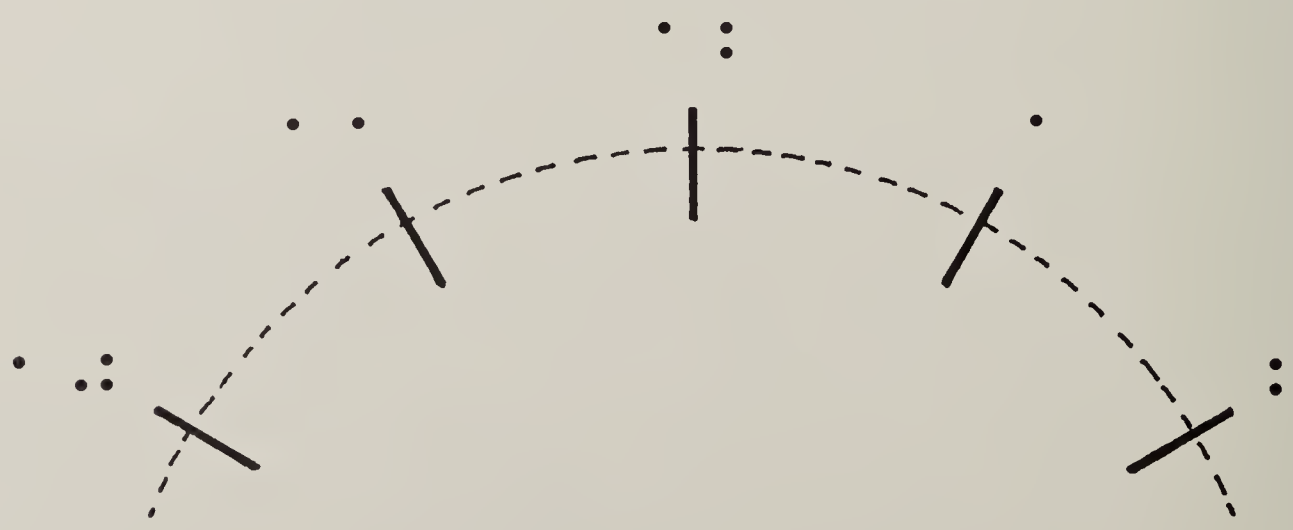
Clocks can be made with or without numbers, depending on their use. Clocks without numbers must indicate the position of 12 to the reader in another way. The symbol for 12 needs to differ from the symbols that indicate 1 to 11. The suggestions shown here are some possibilities.



A special symbol for 12 may not be necessary if the clock face is bound into a braille book or appears in an area with braille text. In these circumstances, the braille text or the binder holes on the left-hand side of the page indicate the direction in which the page is to be read, and the symbol for 12 will always be uppermost on the clock face.

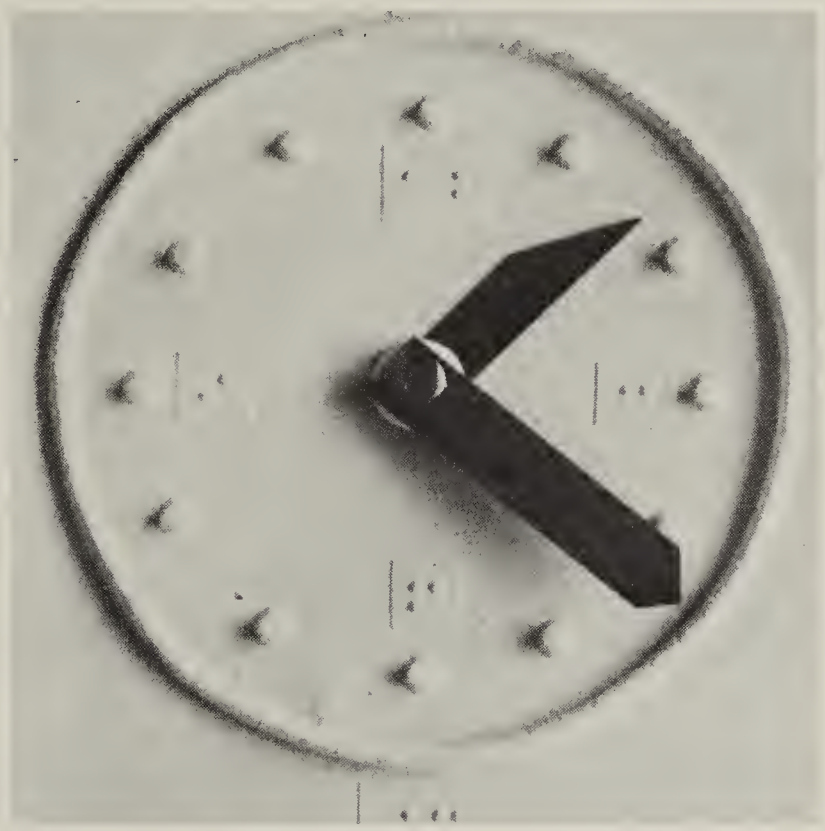
Numbers can be placed either inside or outside the circumference of a clock face. Placement depends on the amount of space surrounding the clock, its position on a page, and its relationship to the text.

Numbers placed outside the circumference of the clock are most easily and quickly understood by all readers. The distance from the clock's outer edge should be approximately 1/4 in. (6 mm). This number placement requires the largest layout area (4 in. to 4 3/4 in. [10 to 12 cm]), as shown here. (Note that it is not necessary to use the braille number symbol with clock numerals.)



If there is little space around the clock face, the numbers could be placed within the circumference of the face to avoid

a cluttered layout. Place them approximately 1/8 in. to 1/4 in. (3 to 6 mm) from the inside edge of the circumference. For this placement, a larger clock face may be needed in order to avoid confusion within cramped quarters. This placement is not successful with clocks that have movable hands. The hands tend to cover the numbers as the reader moves them around the face. For this type of clock, it is preferable to use symbols (dots or lines) instead of numbers.

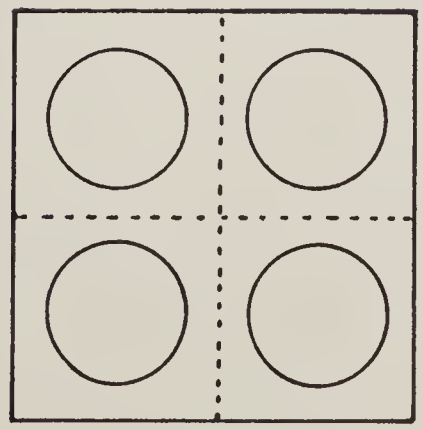


A clock with both dots and numbers. The outline of the clock face is made with string. The hands, which are movable, are made of plastic. The dots are punched from a piece of leather.

Clock Package

A series of clocks with permanently placed hands, four clocks to a page, 12 pages in a series, could be produced in plastic, embossed on braille paper, or made on microcapsule paper. The clocks would show the time from 1 to 12 o'clock. Each page could be devoted to one hour: the hour (12:00), one-quarter after the hour (12:15), the half hour (12:30), and three-quarters of the hour (12:45). If so desired, these clock faces could be used individually by cutting along dotted lines dividing each page. Whether braille numbers, dots, or other symbols are printed on the clock faces is up to the teacher or the producer. Numbers could also be added after the displays have been produced.

A page of one or four clocks with movable hands should also be included in the package. The clock package can be used as a teaching aid or for games for one or more children.

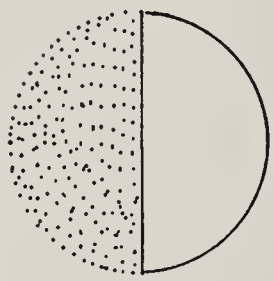


FRACTIONS

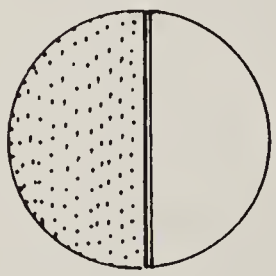
A fraction is a quantity that is less than one unit or is expressed as the sum of a number of parts of a unit. Fractions in graphic form are often expressed using clocks, circles, or other geometric shapes. For clocks, the whole hour, the quarter hour, the half hour, and three-quarters of an hour are understandable to most readers and are easily portrayed.

Circles and Parts of Circles

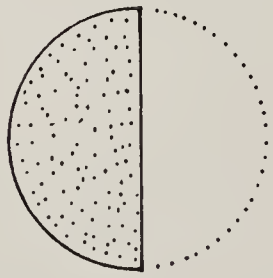
In print, circles can have patterned or colored sections to denote a fraction of the whole area. In graphic displays, such sections must be made into textured areas that give the blind reader the same information through his or her fingertips. It is important to choose textures that can clearly be divided by lines.



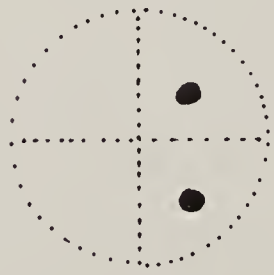
A natural line can be made by using two different textures, such as a circle of heavy paper and a section of fine-grade sandpaper.

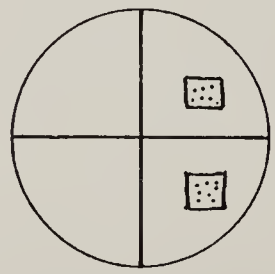


A circle of heavy paper with an embossed or pin-pricked area can be divided by a thread line.



Sandpaper or any other type of texture can be glued on top of a circle that is embossed directly onto the braille paper.





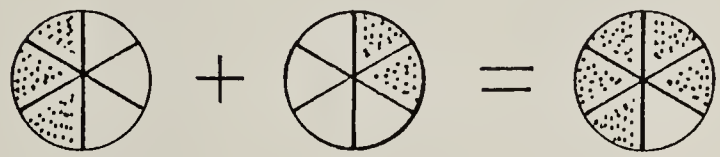
Symbols—dots embossed with standard or jumbo correction tongs, small squares of sandpaper, or dots made with a hand punch, for example—can be added to cut-out or embossed circles.

A large selection of lines and patterns is available for microcapsule paper displays, because these textures can be made with pen and ink. When making original drawings, be sure to leave a white corridor between textured areas (see "Black Areas and White Areas," Chapter 2).

The following examples illustrate the use of graphic "circle" fractions for addition:

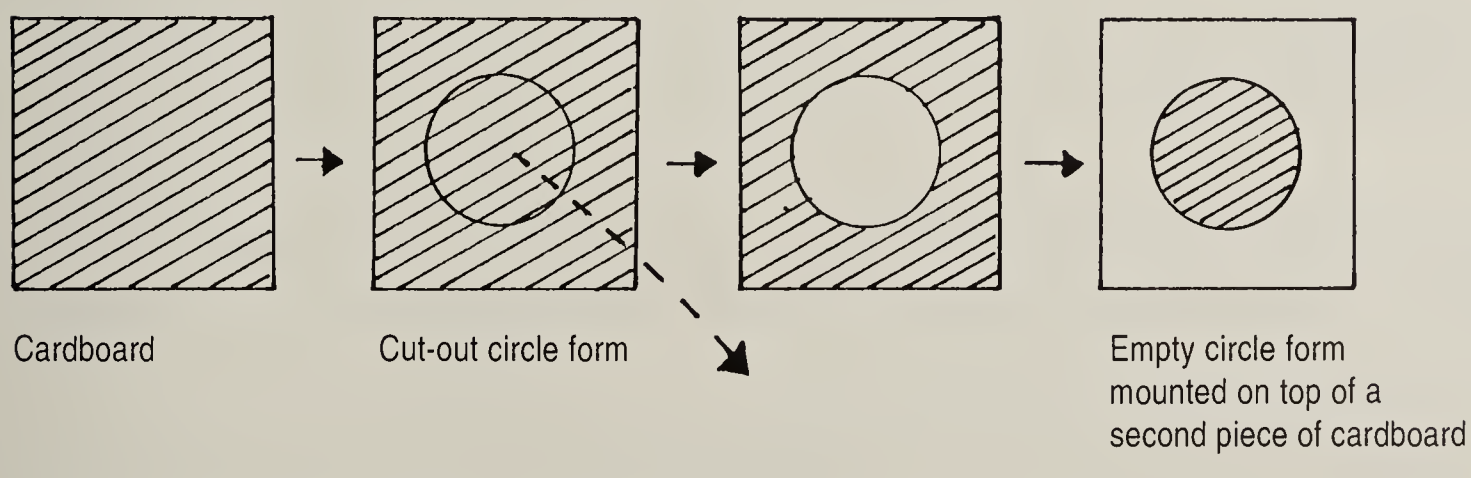
2 1/2 + 1 1/4 = 3 3/4

1/2 + 1/3 = 5/6



3/6 + 2/6 = 5/6

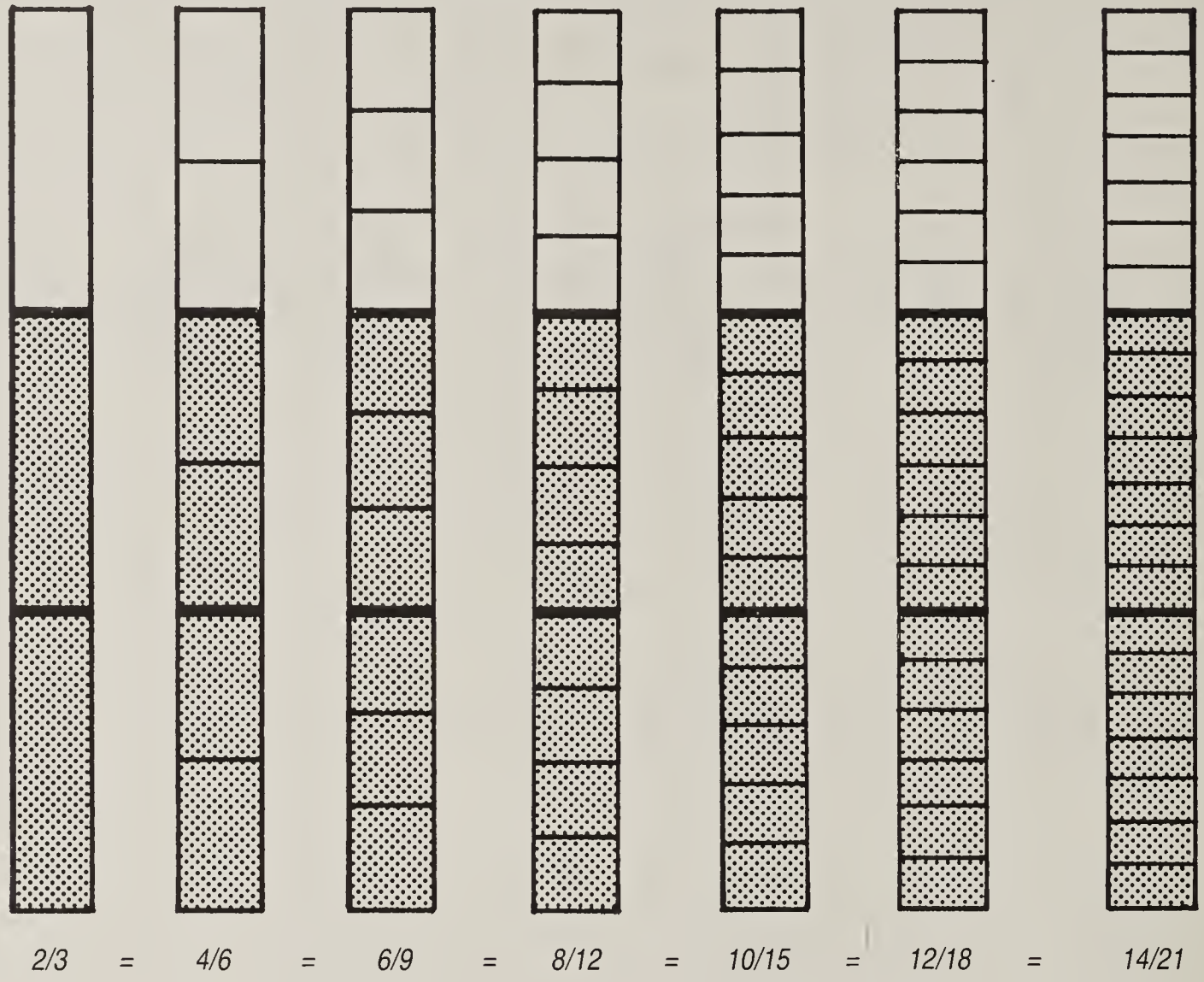
Fractional sections of circles cut out of sturdy cardboard can be used on a flannel board, on a magnet board, or in a relief circle form (see also "Displays with Movable Parts," Chapter 2). The fraction, written on a braille label, can be attached to the back of its circle section. The circle form can be cut out of cardboard in the following way:



The master can be used for one or many copies (in a vacuum-forming machine). For proper fit, the circle sections must have the same circumference as the circle that was removed from the cardboard.

Geometric Forms

Graphic fractions can also be shown in squares, in rectangles, and in long columns. The following illustrations, all in the actual size, are an example of the various forms:



2/3 = 4/6 = 6/9 = 8/12 = 10/15 = 12/18 = 14/21

The following are several ways to produce fraction figures.

Fine-grade sandpaper edged with thread, marked by thread dividers.

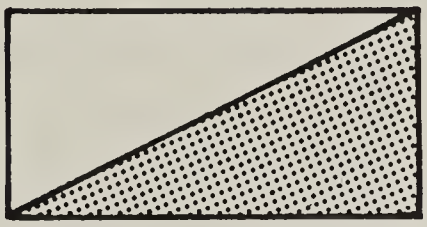
Fine-grade sandpaper, with empty squares edged with thread, and marked by thread dividers.

Embossed figure, with jumbo dots made with a correction tong.

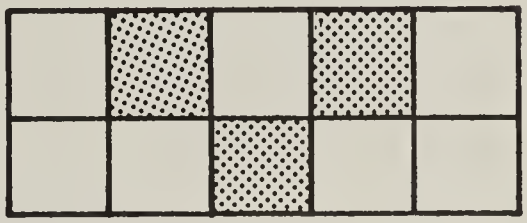
Paper or cardboard squares glued to a background sheet, with the empty squares finely embossed.

Here are other fraction figures produced with sandpaper and thread.

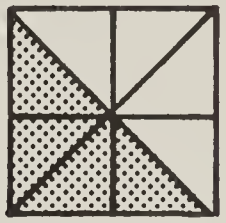
1/2



1/2



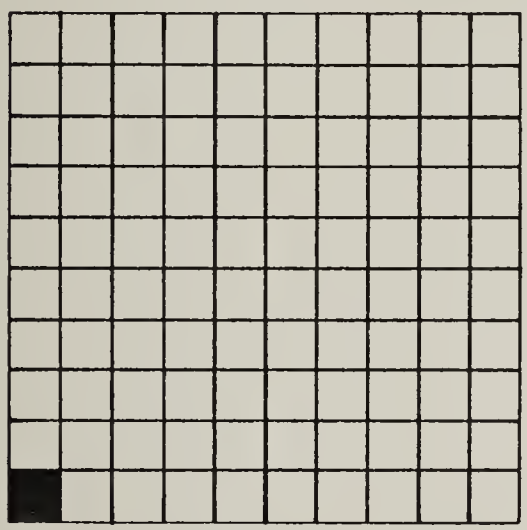
3/10 with texture
7/10 without texture



4/8 = 1/2

Percentage

Percentage is calculated on the basis of a whole divided into one hundred parts:



1 = 100%

1/100 = 1%

1/2 = 50%

1/4 = 25%

1/5 = 20%

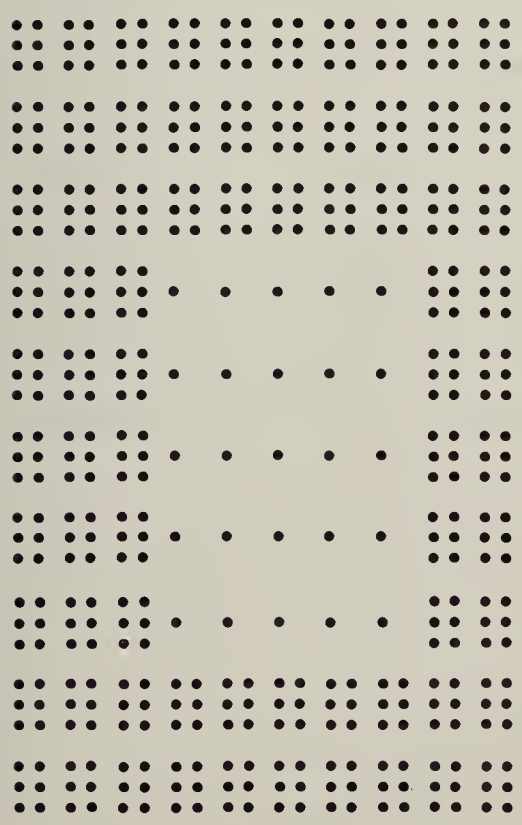
1/10 = 10%

1/3 = 33%

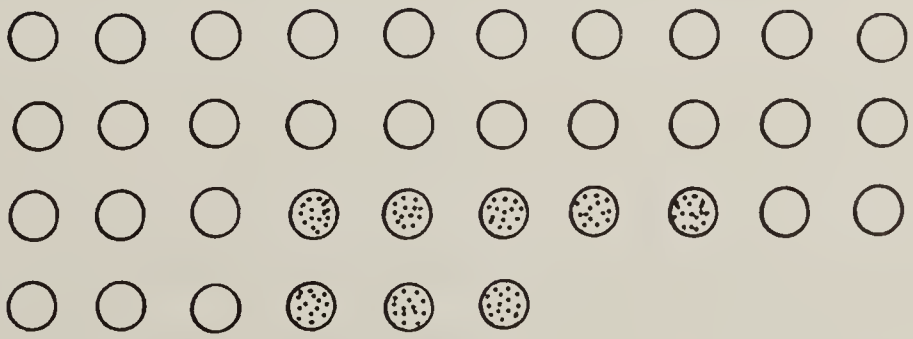
1/8 = 12.5%

3/4 = 3 x 25% = 75%

Percentage figures shown graphically are the same type and follow the same principles as those used to present fractions. The figure of braille cells shown here (see A), whose accompanying problem asked what percentage of the figure

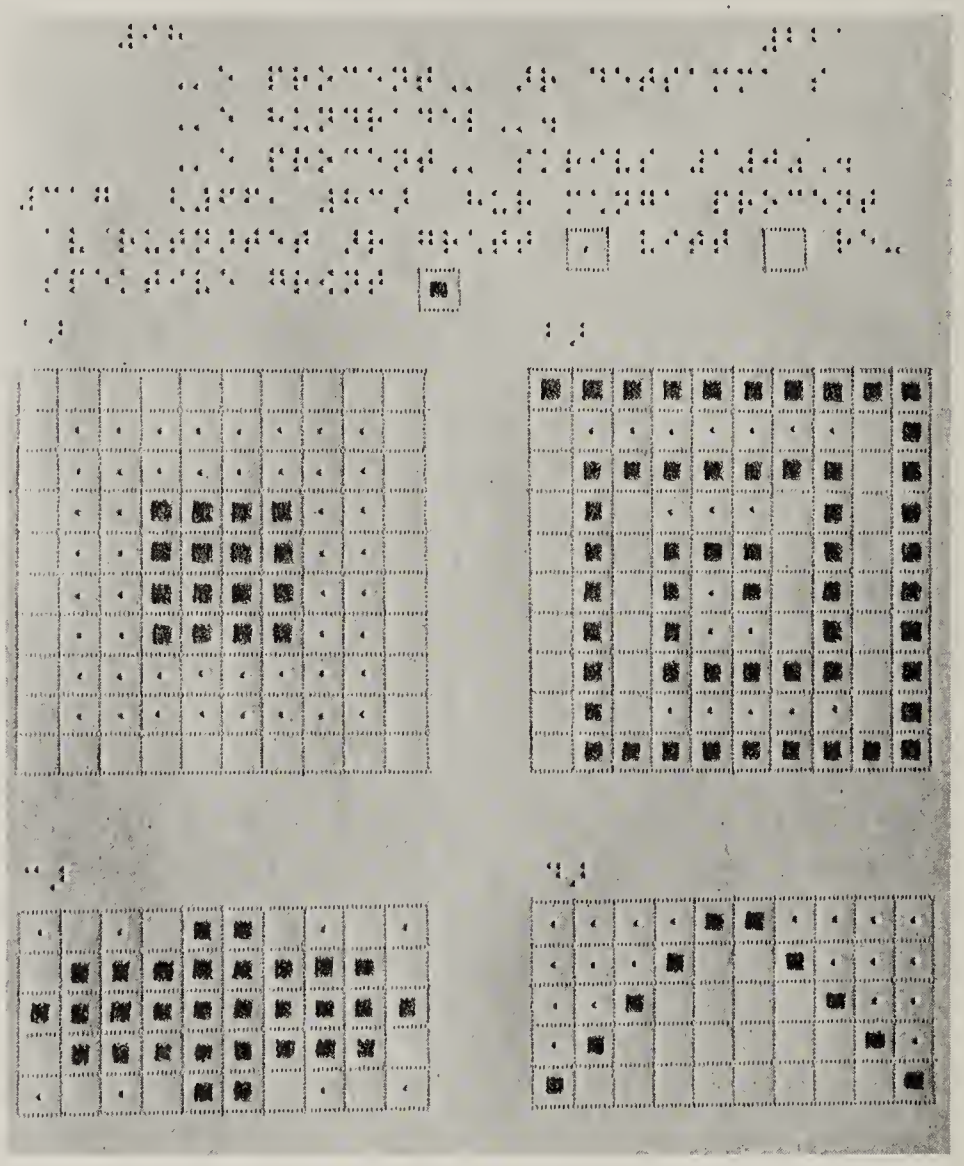


A.



B.

was covered by single dots, can be done on a braillewriter. The same figure could be made with hand-punched dots of thick paper or cardboard and fine-grade sandpaper. Part of it is shown (see B). A pop sheet for mathematics, 10 x 10 rows of dots, is also useful in teaching percentages.



A page of problems in percentages. The figures in the textbook were colored

gray

white

and green

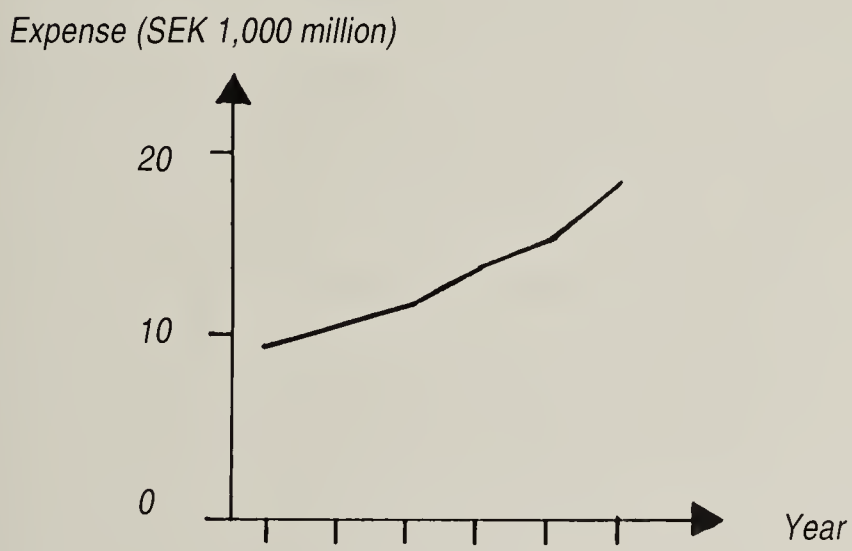
STATISTICS

Statistics is the branch of mathematics that deals with how one gathers, studies, and draws conclusions from numerical information. The same numerical information can give different impressions, depending on the layout of the graph. Producers of material for visually impaired people should be particularly aware of this point. They must enlarge printed graphs and often change their layouts to accommodate brailled or large-print information. In doing so, will they be changing that information?

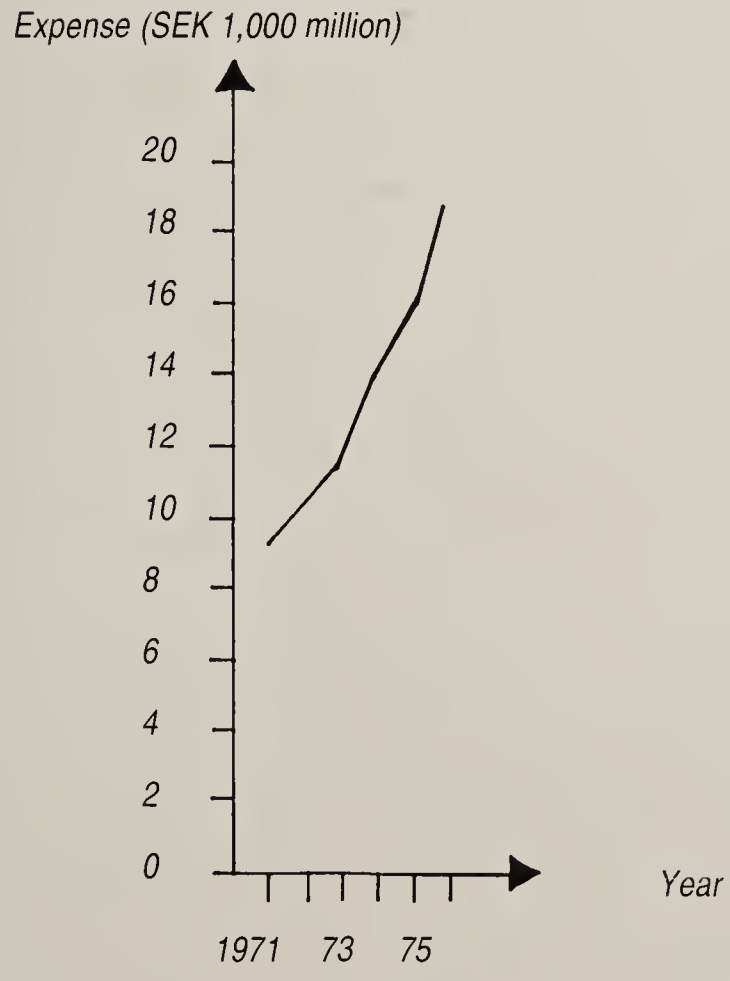
The three graphs that follow present the same information in somewhat different ways that may have an impact on how the information is interpreted. They are all based on the facts

shown here concerning the expense of old-age pensions in Sweden (from Statistiska Centralbyrån, 1977). The denominations are in 1,000 million Swedish kronor.

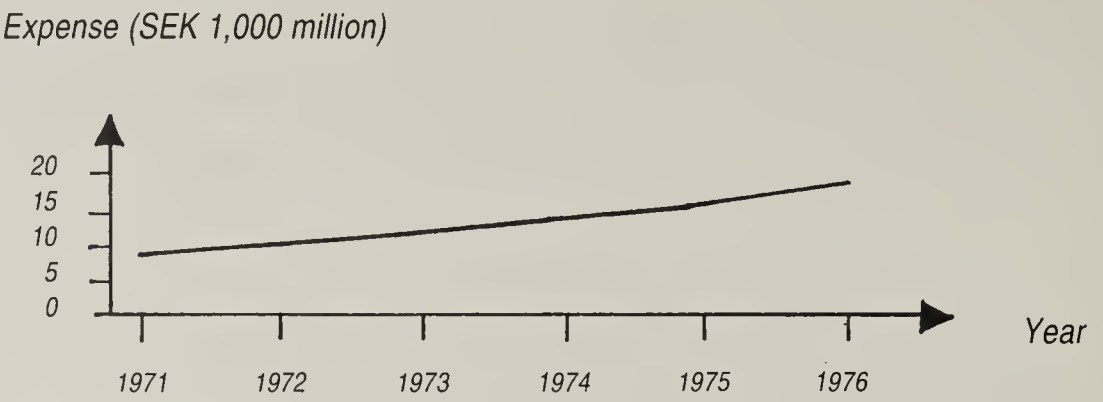
Year	1971	1972	1973	1974	1975	1976
Expense	9.2	10.2	11.4	13.8	15.9	18.8



Expenses for old-age pensions in Sweden, 1971-76, in 1,000 million Swedish kronor.



In this version of the graph, the scale of the Y-axis is elongated and the scale of the X-axis is diminished. This gives the impression that the cost of old-age pensions has risen drastically.



In this version, the scale of the Y-axis is diminished and the scale of the X-axis is elongated. This gives the impression that the cost of old-age pensions has been moderate.

GRAPHS AND DIAGRAMS

Although the words "graph" and "diagram" and "diagram" and "display" have been used interchangeably in this book, their usual definitions are as follows:

- *Diagram*: a line drawing that is on a flat plane and is not a perspective drawing.
- *Display*: an arrangement of lines and forms on a printed or relief page; an illustration or a layout.
- *Graph*: a drawing depicting the relationship between certain sets of numbers or quantities by means of a series of dots, lines, and so on, plotted with reference to a set of axes.

Graphs and diagrams are the pictorial presentation of statistics. They are an attempt to make written facts more understandable for sighted readers. Whether these graphic displays can, or should, be transposed into relief material for blind or visually impaired readers depends on the judgment of the editor of the material, who must consider if the graphic material adds further information to the text or if a word description of this material would be easier for the blind reader to understand. The editor must also understand the readers who will use the material, their capacity for grasping statistics, and their ability to translate curves and lines into useful information.

Information about the production of the following types of graphs and diagrams is included here: pictographs, bar graphs, line graphs, Cartesian graphs, circle diagrams, and histograms or box graphs. In addition, a number of related topics are discussed. The graphs and diagrams are not presented in order

of complexity but on the basis of similar information for several types of figures.

Valuable reading material for producers and also for blind and visually impaired readers can be found in *Tangible Graphs,* published by the American Printing House for the Blind. This program is designed for maximum student involvement. It consists of a 3-volume student graph text (in braille), student tests, graph test answer sheets, a teacher's guide to the student text and to the graph tests (in print), and graph-construction materials.

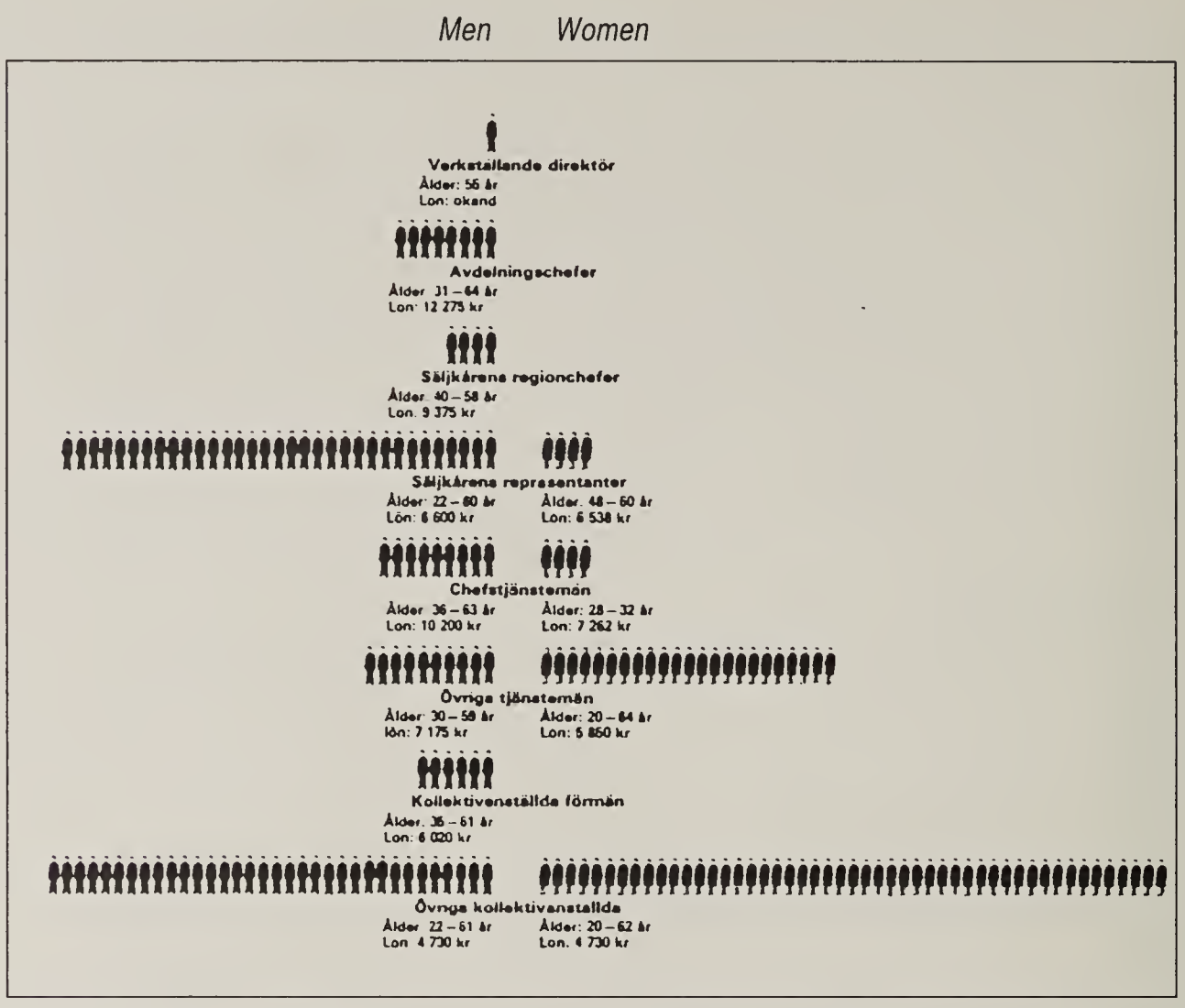
Pictographs

A pictograph is a diagram in which picture forms or parts of these forms represent statistical information. This type of diagram can only suggest the values represented; it cannot accurately portray them.

It is not advisable to attempt a literal transfer of pictograph pictures to a relief display. These pictures are often too small for the blind reader to understand their shape; fractional parts of the figures are not discernible, and the figures are not that important. It is the information and the pattern that this information makes in the layout that are significant, not the people, houses, or cars that portray this information.

Coded symbols (see "Coded Symbols," this chapter) are excellent for use in pictographs. The coded symbol should be presented in the pictograph key in the same size as it appears in the graph, followed by an explanation of its purpose (each figure = 500 men or 1 million houses, for example). If the symbol appears in several forms (to represent 100 percent, 75 percent, 50 percent, and 25 percent, for example), the forms should also appear in the key with the proper values indicated. Your graph loses its meaning if the components are not explained to the reader.

The pictograph shown on the next page portrays complete figures, each one representing a man or woman. Each figure could be substituted by a braille cell. The layout of the graph shows that all figures to the right are women and all those to the left are men. Consequently, there is no need to use more than one type of symbol or one size of symbol, since there are no half or quarter figures.



A pictograph showing the relationship between men's and women's job positions, ages, and salaries in Sweden, from *Matematik HSE 1* (Nyman, 1984).

The use of a 6-dot braille cell makes it simple to produce such a pictograph on a braillewriter or with a slate and stylus. In addition to braille cells, other symbols that can be used are embossed marks made by pressing the end of a screwdriver into braille paper and dots glued onto or embossed into the display (see "Point Symbols," Chapter 6).

The following are several suggestions for symbols in displays using partial figures.

Braille cells: 100 percent, 50 percent.

Boxes cut from braille paper or cardboard, with or without texture, glued to a background: 100 percent, 50 percent.

Boxes cut from braille paper, center line made with a spur wheel, glued to a background: 100 percent, 50 percent.

Boxes embossed into braille paper with a spur wheel: 100 percent, 50 percent, 25 percent.

Sandpaper boxes glued onto background, divisions made with preglued thread or string: 100 percent, 75 percent, 50 percent, 25 percent.

Another version of boxes cut from braille paper or cardboard: 100 percent, 50 percent.

Caution: The symbols must be large enough for readers to distinguish differences and be far enough apart to be easily recognized. They must be uniform in size and elevation throughout a display.

The next pictograph shown on the right, from *Geografiboken* (Forsstrom, Holdar, & Sellergren, 1976), presents the number of inhabitants per square kilometer in each of the Scandinavian countries. The pictograph form is not really necessary for this information. The number of people is already stated, and the comparison can quickly be made in one's mind. However, as an example of a pictograph display, it can easily be made on a braillewriter.

By using the 6-dot braille cell as a coded symbol, you can easily convert this pictograph into a bar graph. Divide the number of inhabitants in each country by 2—their common denominator (57 braille cells take up less space than 114 braille cells). Explain on the graph that each cell equals two people.

The bar graph shown below is the result. In the graph, X is one 6-dot braille cell:

Denmark	XXXXX XXXXX XXXXX XXXXX XXXXX XXXXX XXXXX XXXXX XXXXX XXXXX XXXXX XX
Sweden	XXXXX XXXX
Finland	XXXXX XX
Norway	XXXXX X
Iceland	X

Bar Graphs

A bar graph consists of vertical or horizontal bars whose lengths are proportional to the measure of the data or things being compared. Printed bar graphs can vary in many ways:

- The position of the bars may be vertical, or it may be horizontal, but it is never both in one graph.
- The individual bars may be solid in form, or they may be formed by an outline.
- The bars may have spaces separating them, or they may be formed as a solid mass in a textured area or in a large outlined area.
- The bars may be presented with or without a grid-line background.
- The width of the bars may range from very wide to very thin.
- Several colors or textures may appear within the same printed graph.

Making relief displays of printed bar graphs is not as confusing as it may seem. Once the decision whether to produce the graph has been made (see "To Do or Not To Do?" earlier in this chapter), the producer should keep to the printed graph as closely as possible, provided that the placement of the bars is easily understood by the blind reader and that the graph and text can be easily read.

Change the graph if the printed version cannot readily be transposed to a relief display. The main point is the transfer of the information (the interpretation of increasing and decreasing line trends) to your reader. Keep the graph as uncluttered as possible by using abbreviations and coded symbols that are explained in a key.

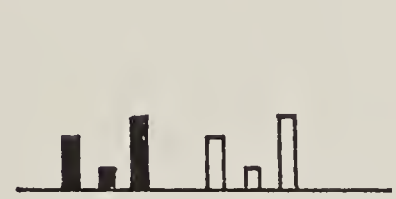
When enlarging a bar graph to accommodate brailled information, be sure that the bars are not separated from each other so much that the relationship between the bars is difficult to understand. Remember that your reader is not able to gain a quick overall view of the graph—he or she must trace the lines bar for bar.

The following are materials to use to make bars:

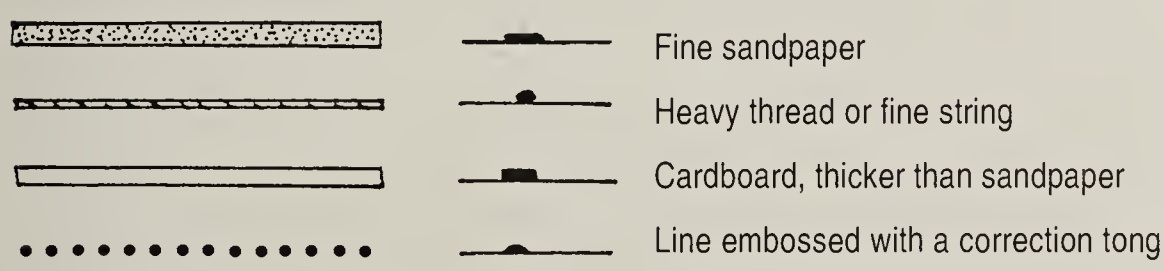
- the 6-dot braille cell (turn the diagram so that the braille cells, one after another, form the bars),

- tapes of various widths and textures,
- sandpaper strips of varying coarseness,
- coarse thread or string,
- cardboard or paper strips,
- preglued thread on paper strips (see "Areal Symbols," Chapter 6),
- preglued thread or string to form outlines of bars,
- correction tongs and jumbo-dot embossers,
- ribbons of various widths and textures,
- strips of metal or plastic screening,
- wire,
- embossed lines made by various spur wheels and tongs, and
- various patterns that can be drawn for microcapsule paper displays.

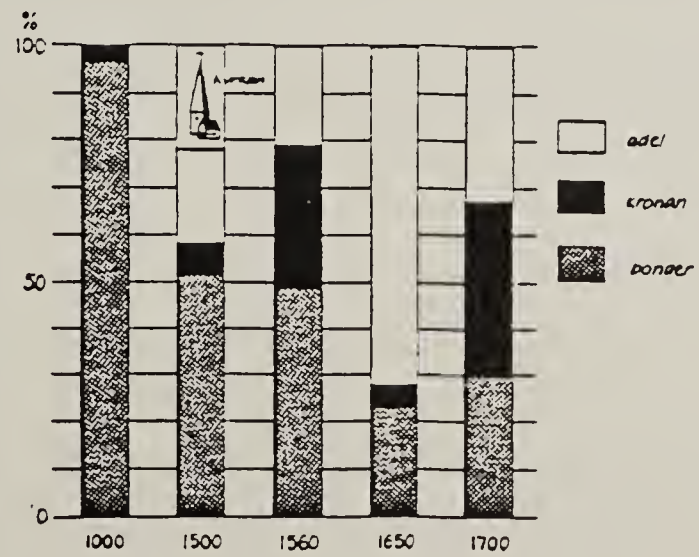
Note that bar patterns, guidelines, and grid lines in a one-elevation graph should be so contrasting in character that they cannot be misunderstood, such as those shown here on the right.

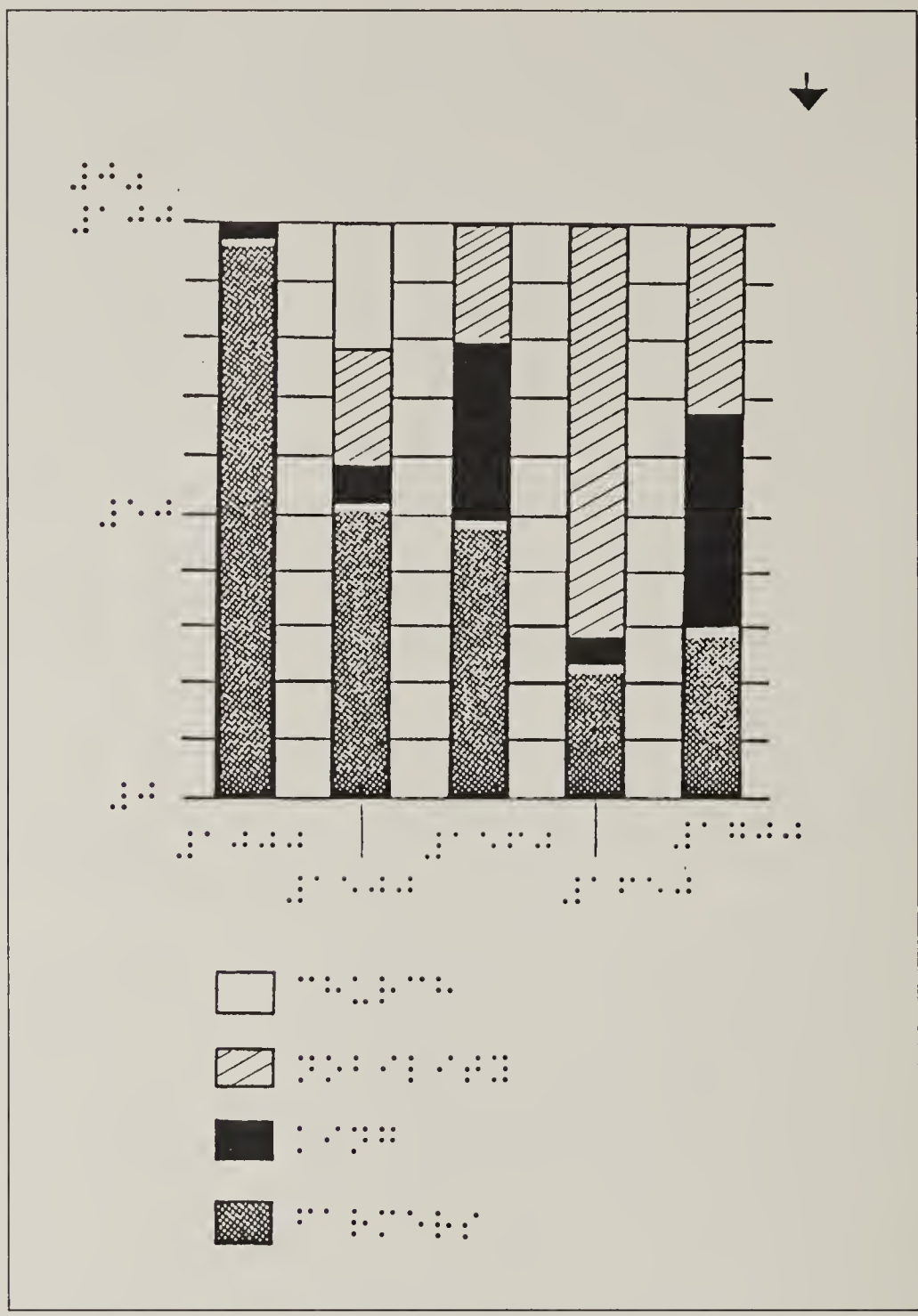


Also note that solid bars are easier to read than are bars with an outline form for each bar. Different types of bars for graphs with several types of information should be made from materials that are of decidedly contrasting character:



The graph shown below was made into a bar graph on microcapsule paper. The text of the original graph read: "Who



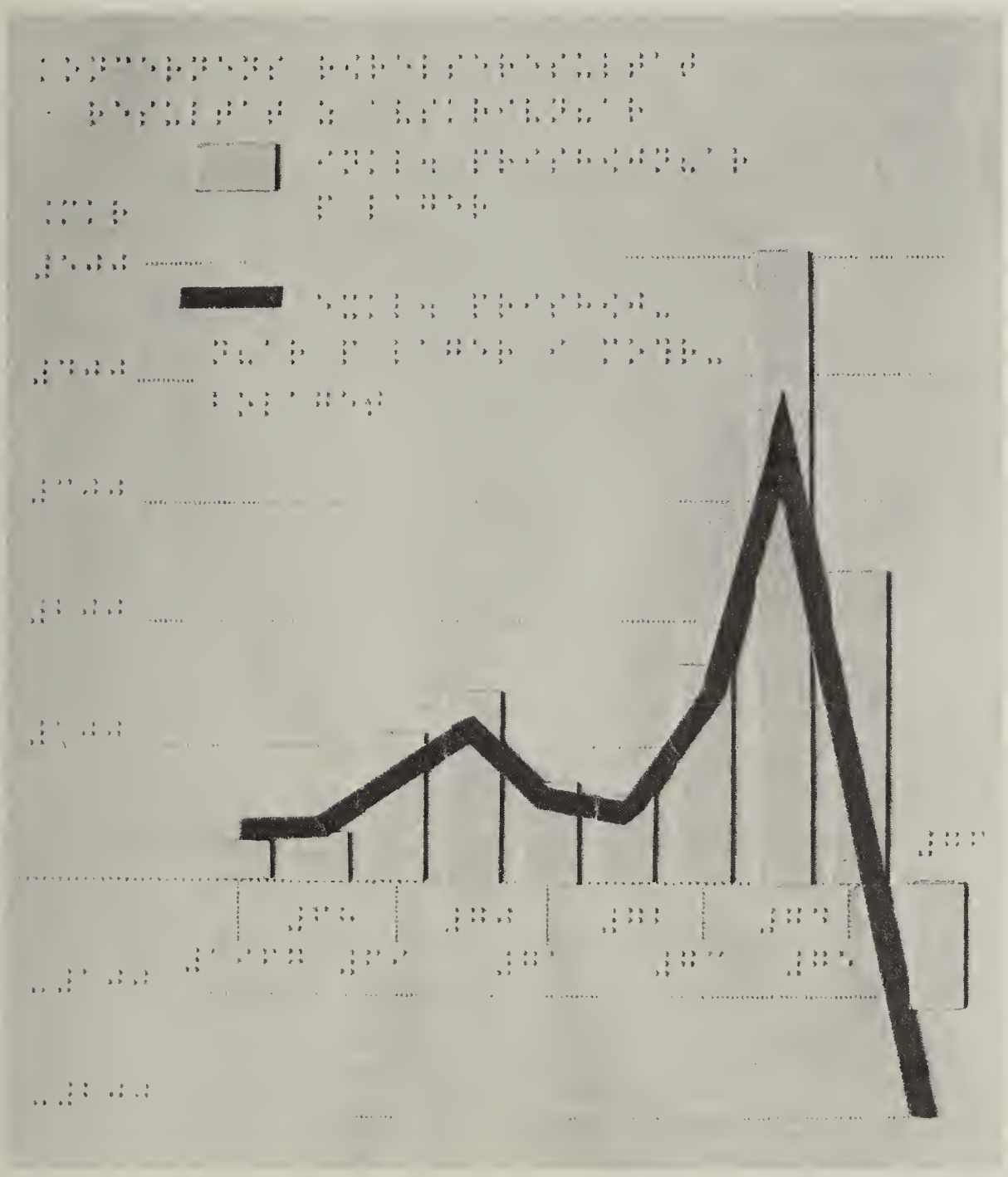


owned the forest between the years 1000 and 1700?" (Eklund, Thorén, & Åberg, 1984). The graph was made into a relief display, shown above, with a minimum of changes. The church drawing was removed, and its blank area was added to the key. The remaining white areas, representing what belonged to the nobility, were given a striped texture. This fact was also added to the key. White bands were made between the textures. They allowed each texture to stand out as an individual entity.

Axes

An axis is a fixed line along which distances are measured or to which positions are referred. Axes are a distinctive feature

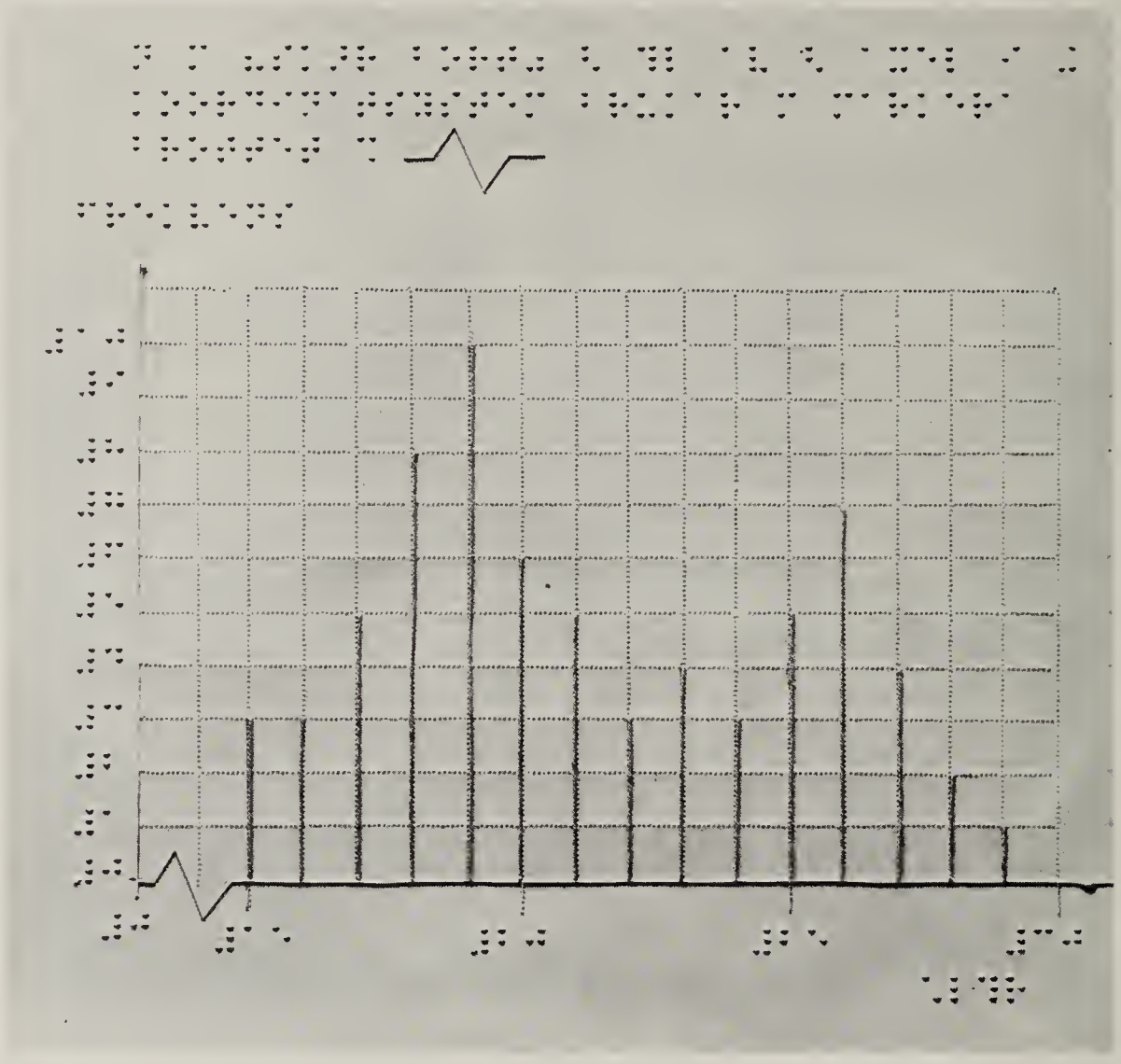
common to all graphs. Two axes, placed at right angles, are basic components of a bar graph. The horizontal axis is referred to as the X-axis and the vertical axis as the Y-axis. These axes may be used independently or with a grid-line background. Materials used to make axes include fine or coarsely embossed lines from a spur wheel, preglued string or thread with or without a knot at the end of the string to indicate direction (an arrow symbol), and sewing machine lines (made with or without thread in the machine).



A graph with cardboard bars, a sandpaper line, and finely embossed axis and guidelines, depicting the use of horizontal grid lines, one for each unit of 100 million Swedish kronor. The standing bars show the rise of prices in present stocks. The sandpaper line shows the stock in the warehouse of the mother company, excluding the rise in prices of this stock.

There are times when sections of a graph are not necessary. Reduction of an area on an axis can be done in the same way as it is in printed graphs, by means of a shortened axis line. The symbol shown on the next page denotes for the reader that such a line has been used. Readers using relief displays

must be informed about the use of this symbol. Repeat the symbol and an explanation of it in a key or directly above the graph itself, as shown in the illustration here.



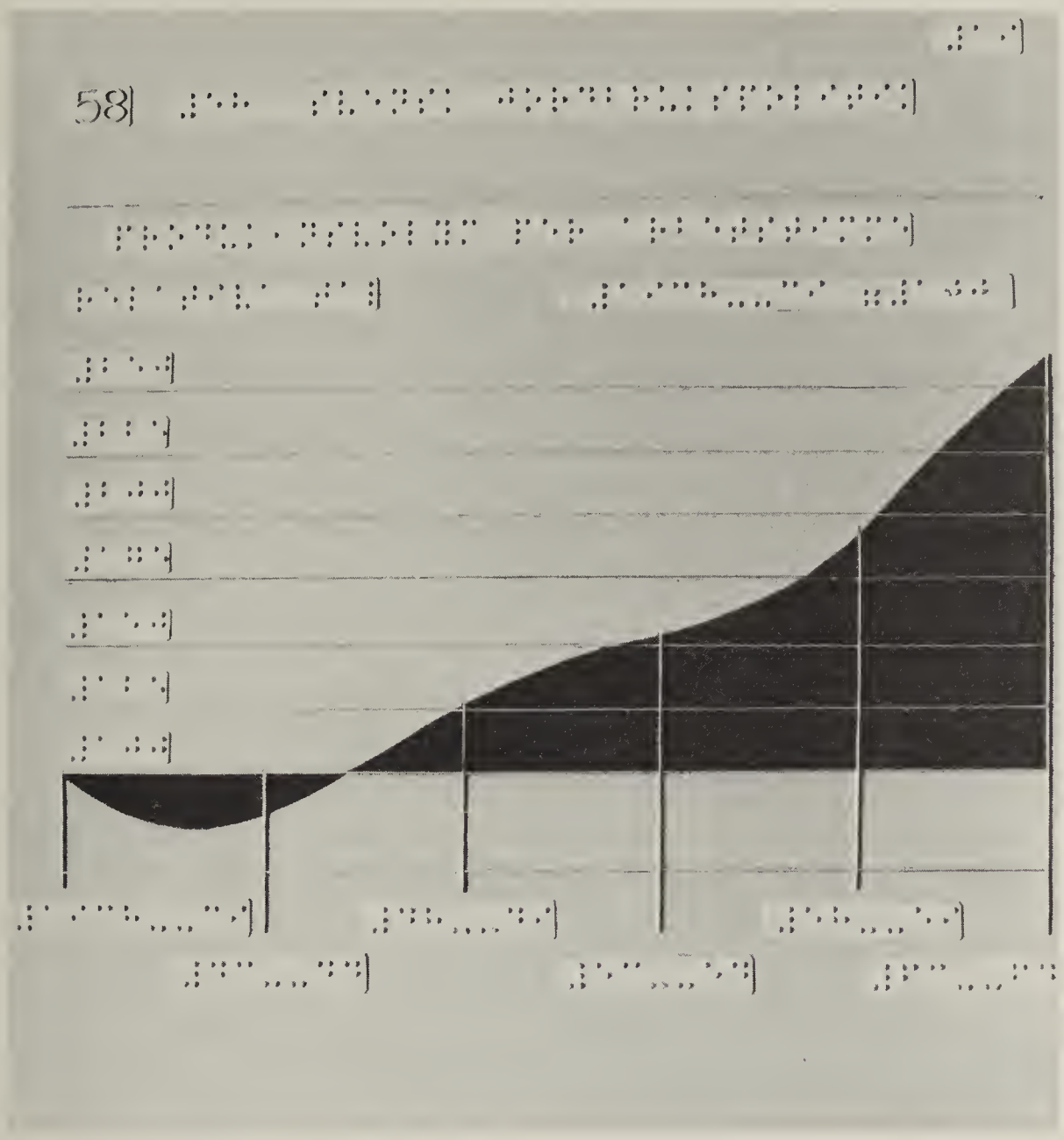
A graph in which a shortened axis line, the appropriate symbol, and an explanation in the key are used.

Grids and Guidelines

Grids consist of networks of evenly spaced horizontal and vertical lines that may cover the background area of a bar-, line, or Cartesian graph. These lines make it easier for sighted and blind readers to locate particular areas in a graph layout.

Guidelines are evenly spaced lines that cross the graph layout in a vertical or horizontal direction. They serve the same purpose as grid lines. However, they are used more in defining the relationship between the components of the graph than in the presentation of the exact numerical value of these components.

Guidelines and grid lines, if used, will begin at tick marks (see "Tick Marks," next section). These tick marks, placed at evenly spaced intervals along both the X-axis and Y-axis, indicate the position of the numerical points of the graph.



This illustration is an example of guidelines and grid lines used together in the same graph. The lines are made of coarse thread (carpet thread), and the dark area is of fine-grain sandpaper. The graph illustrates production volume per working hour in Sweden in 1938-39.

Use of Grid Lines

Grid lines are an important feature of bar and line graphs for sighted readers. Their presence in relief displays for blind readers is somewhat less self-evident. Textbook grids are often printed in another, lighter color from the bars or lines they support, which immediately reduces them to a background position, leaving the bars and lines to stand out in bold contrast. In a relief display, color must be substituted by texture, and finding a line that will not vie for attention with the bars or lines of the graph is not an easy task.

Grids in one-elevation graphs (graphs embossed on braille paper or microcapsule paper displays) can be a decided hindrance to a reader who is tracking a line. The grid is the same height as the line. Special precautions must be taken, since despite the wide areas of white that should be left around the bars and lines of the graph and prominent bars and lines that have been overemphasized to give them more

contrast to the grid, the grid will still be too obvious. Thus, it is safe to say that when the precise location of points is not necessary, grid lines are not necessary. However, grids are needed in those graphs that must show the exact location of points, since the reader *must* be able to determine the values of the graph. There are times when the presence of a grid is the only way these values can be shown. Finely embossed grids made with a spur wheel or grids formed with thin, preglued thread have served this purpose well, especially if the material used in the bars and lines of the graph is of a strong contrast in size, elevation, and texture.

Grid lines are often used on buildup masters of bar and line graphs. Their final shape has been widely discussed, but an ideal solution has not as yet been reached. Barth (1983a; see also Barth, 1983b) found that it took blind students in the 4th through the 12th grades 144 percent more time to track lines embedded in a raised grid than to track ones displayed against a smooth background. This occurred despite the fact that the tracked lines and grid lines were highly discriminable, different in elevation, and separated by a distance of 1/8 in. (3 mm). In an attempt to alleviate this problem, Barth (1983b) examined a new type of grid composed of incised lines. Compared to a raised grid, the incised grid facilitated the performance of three graph-reading tasks: line tracking, location of minimum and maximum data curve peaks, and location of point symbols. Students' performance of these tasks with the incised grid was in fact similar to that achieved with no grid present. Furthermore, the incised grid did not impair the students' ability to locate accurately the X and Y coordinate values of a graph point. The students' performance of this task was comparable to that attained with the raised grid.

No easy and efficient system for incising grids on a paper buildup master has been found, although incised grids can be made in metal foil masters by impressing the grid image into the foil sheet, which has been placed on top of a rubber pad. Perhaps this could also be done with braille paper. A smooth line can be made with a stylus on lightly dampened paper, also laid on a rubber pad. I do not know if this grid will stand up when the bars or lines of the graph are embossed or glued onto the paper and the master is run through the vacuum-forming machine. You may have a better solution.

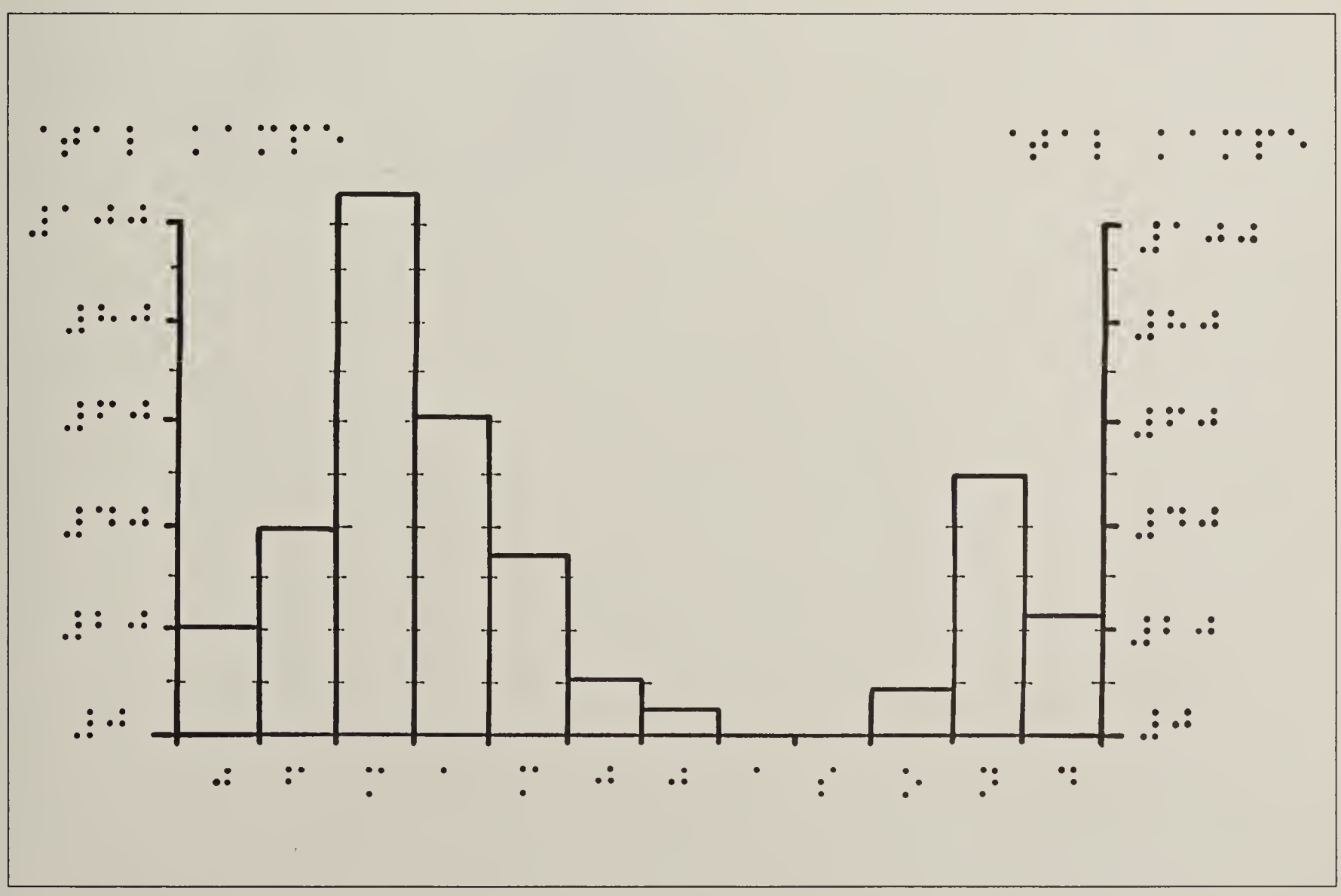
Additional Considerations

Grid lines must be straight and evenly spaced; they must intersect each other at right angles; and they must be separated by at least .5 in. (13 mm). If the grid lines of the original graph are too compact, exclude every other line in the relief display. See to it that tick marks and numbers for the eliminated lines are marked along the axes of the graph. Blind readers can identify the position of dots at one-half square locations without difficulty on a .6 in. (15 mm) square grid (Levi & Amick, 1982).

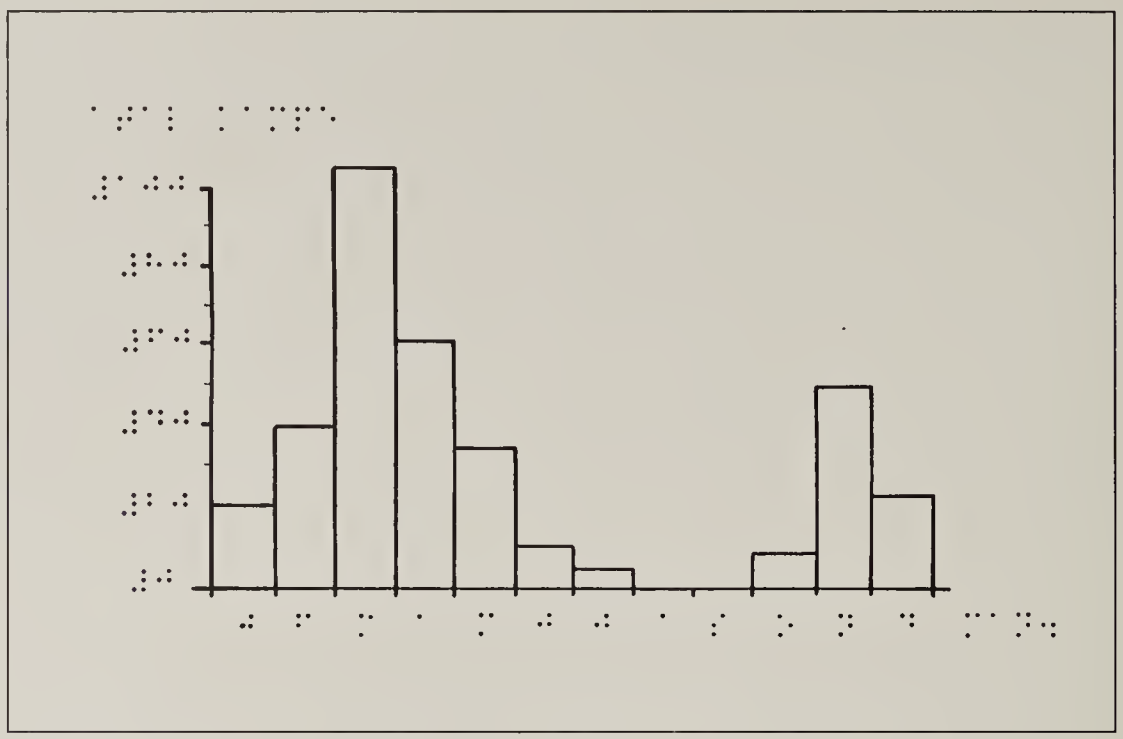
Pause before making a relief display of a printed graph. Read the text material accompanying the graph and look closely at the graph itself. You may have to make several changes to suit the needs of your blind readers.

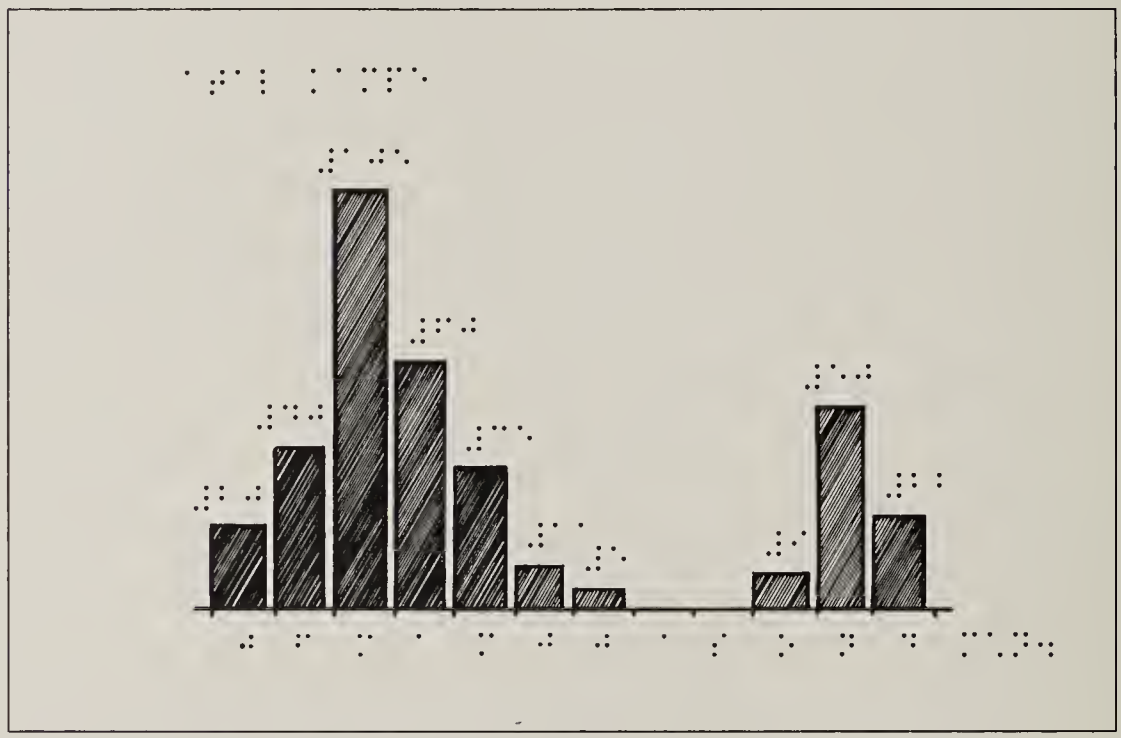
The series of graphs on the following pages are variations based on the same microcapsule paper graph from Denmark shown below that was submitted for testing. None of these graphs is better than the others. This group is included to show that there is more than one way to present the same material.

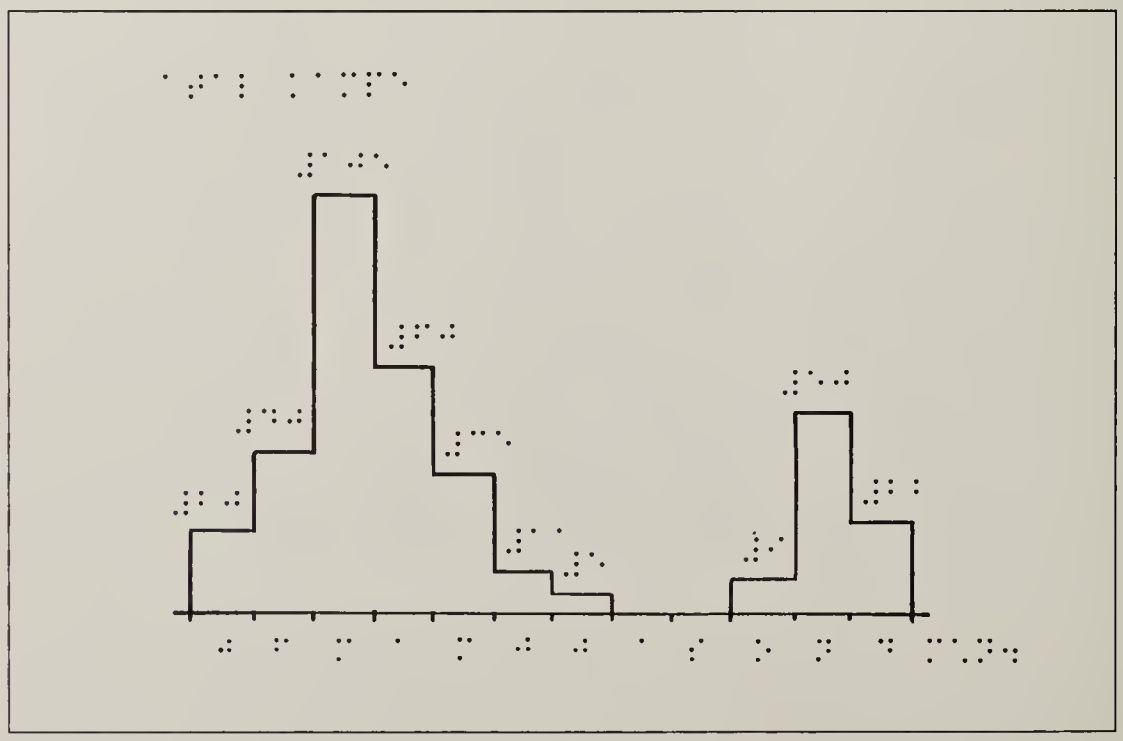
The original microcapsule paper graph.

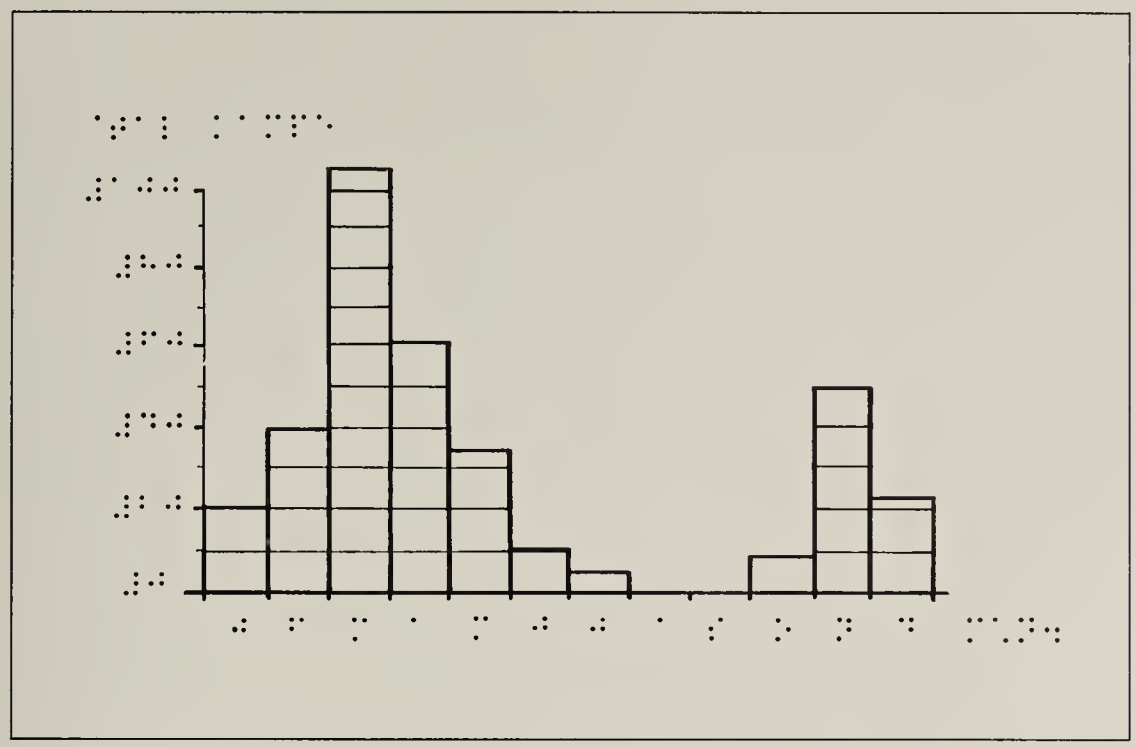


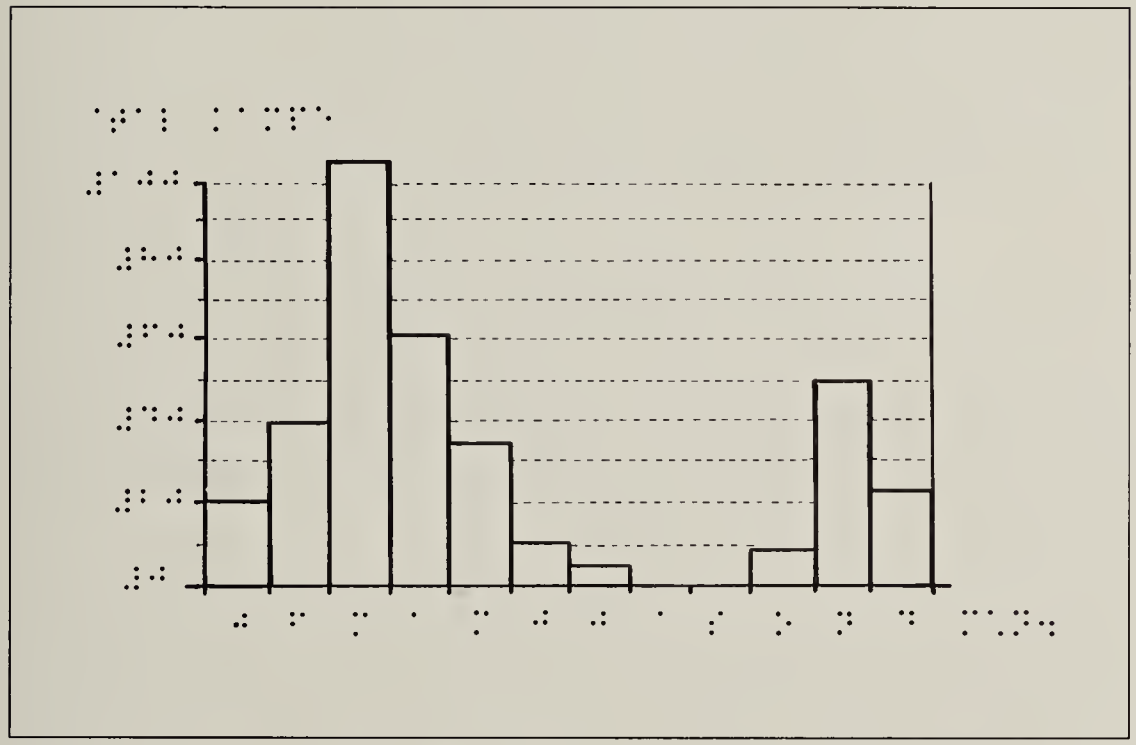
A series of graphs based on the original graph.

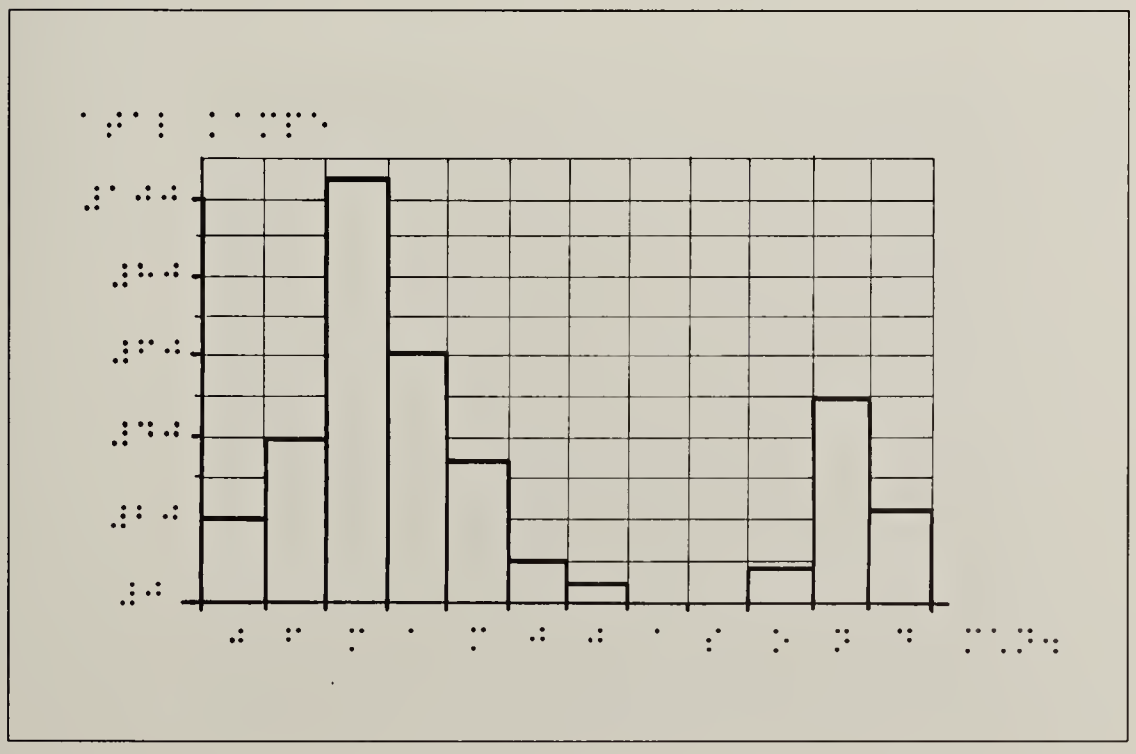








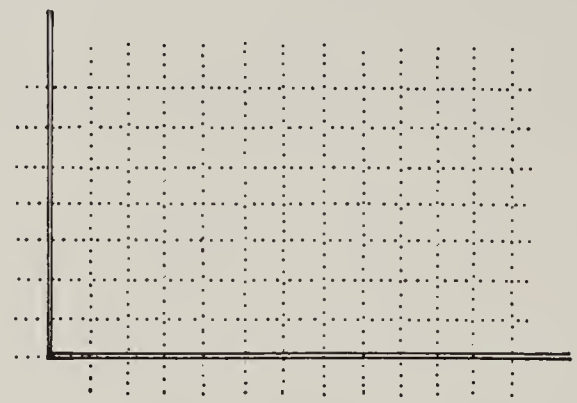




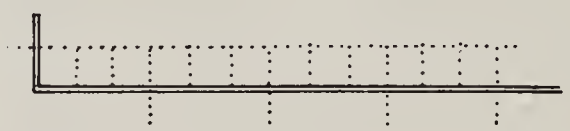
Tick Marks

A tick mark, also called an index mark or a scale mark, represents a point on a scale. Tick marks should be easy to find, evenly spaced along a graph's axes, and long enough so that it is obvious which mark belongs to which number.

Tick marks can be the same texture as the axes lines, the grid lines, or the guidelines. They are often the extension of grid lines or guidelines, as shown here.

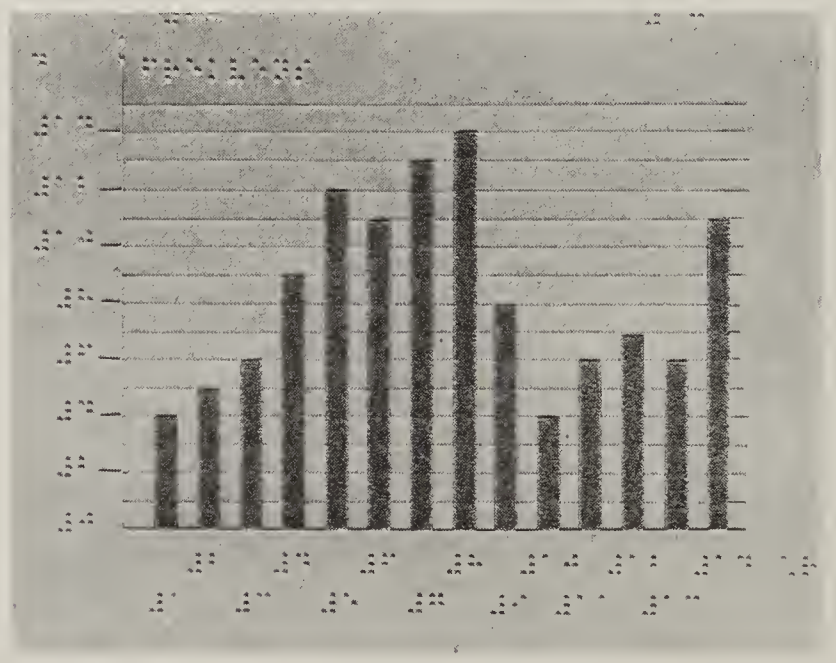


However, every grid line may not end in a tick mark. The extent of these marks depends on the information in the graph.



For special emphasis, the marks can be made of a contrasting material, such as coarse thread or string glued across a thin thread or embossed line.

There may not be enough space for a long series of numbers along an axis. In this case, stagger the numbers and elongate every other tick mark to eliminate crowding the text on the page. Sometimes, every other mark is left out entirely, as in the bar graph shown below.



A bar graph with embossed guidelines. The axes and tick marks are made of thread. A knot at the end of the Y-axis indicates direction.

There is no perfect solution for the placement of numbers beside tick marks: It depends on the amount of space available for the numbers on a particular graph. The size of the braille numbers may make it necessary to skip over every other number in a series. If you do this, be sure there are tick marks at the places where numbers are omitted. The reader should be able to figure out which numbers are missing. Be consistent in the placement of numbers in relation to tick marks within the same graph. Try not to place some numbers above the line (see 1), others opposite the line (see 2), and some below the line (see 3). Also, the placement of numbers should be the same within a particular series of graphs.

When trying to place dates in relation to tick marks, remember that dates can be shortened. For example, you can begin the series 1984, 1985, 1986 with 1984, followed by 85 and 86. Numbers can also be replaced by a letter symbol (a=1984, b=1985), provided that a key accompanies the graph.

Line Graphs

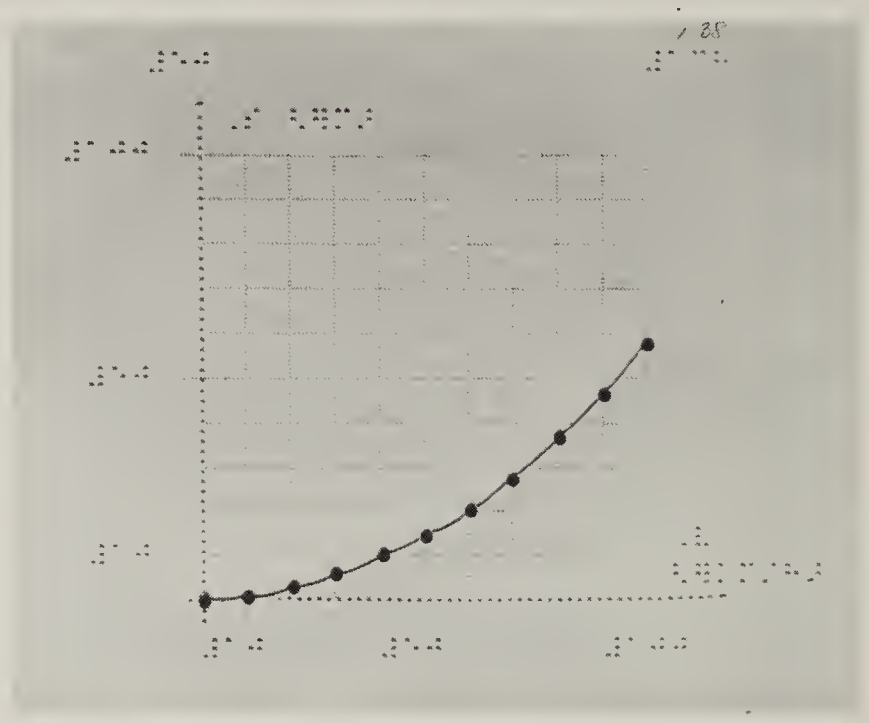
A line graph is a diagram indicating a relationship between two or more things by means of a system of dots, curves, bars, or lines. In elementary arithmetic, the purpose of the number line (see "Number Lines" earlier in this chapter) is to teach the relationship between numbers. This is the first type of graph that a student in beginning mathematics will encounter—it is a one-axis graph. Grid lines, guidelines, axes, and tick marks for all types of line graphs are the same as those for bar graphs.

Lines of a graph that are surrounded by quite a bit of white area are easier to read than graph lines that are tightly intertwined or that go through a heavily textured area. Decide which of the crowded lines should be dominant to the touch through your choice of texture, or use the step-by-step technique. Following are several examples of line graphs.

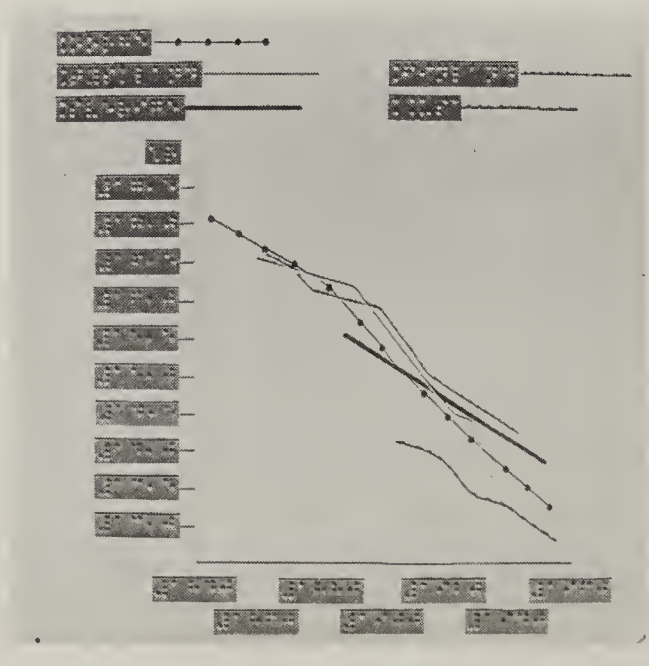
The line graph at the top of the next page was made from the table shown here on the right. The numerical values were placed in a coordinate system (see "Cartesian Graphs," next section), and a curve was made that connected these points. The following materials were used: line—carpet thread; points—cardboard dots from a hand punch; grid—finely embossed lines from a spur wheel; and axes—embossed lines from a

v (km/h)	s (m)
0	$0/180 = 0$
10	$10^2/180 = 0{,}6$
20	$20^2/180 = 2{,}2$
30	$30^2/180 = 5{,}0$
40	$40^2/180 = 8{,}9$
50	$50^2/180 = 13{,}9$
60	$60^2/180 = 20{,}0$
70	$70^2/180 = 27{,}2$
80	$80^2/180 = 35{,}5$
90	$90^2/180 = 45{,}0$
100	$100^2/180 = 55{,}5$

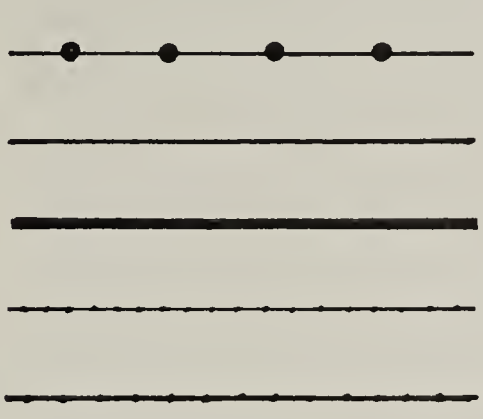
coarse spur wheel. The dot at the end of each axis (an arrow symbol) was made with a jumbo-dot correction tong. In the mounting of the cardboard dots, the thread was stopped at both sides of the dots to allow the dots to be glued to a flat surface. They will thus stay glued longer.



The lines of the next graph symbolize different countries. The graph was enlarged to accommodate the braille text. Otherwise, it is a copy of the printed textbook material. And this is where it fails. The information is too concentrated to allow easy line tracking, in spite of the contrasting texture and elevation of the lines. Enlarging this graph still further would not have helped the situation. The lines are too close together. This graph should have been broken down into several graphs using a step-by-step technique.



The following materials were used:



Thread and cardboard dots

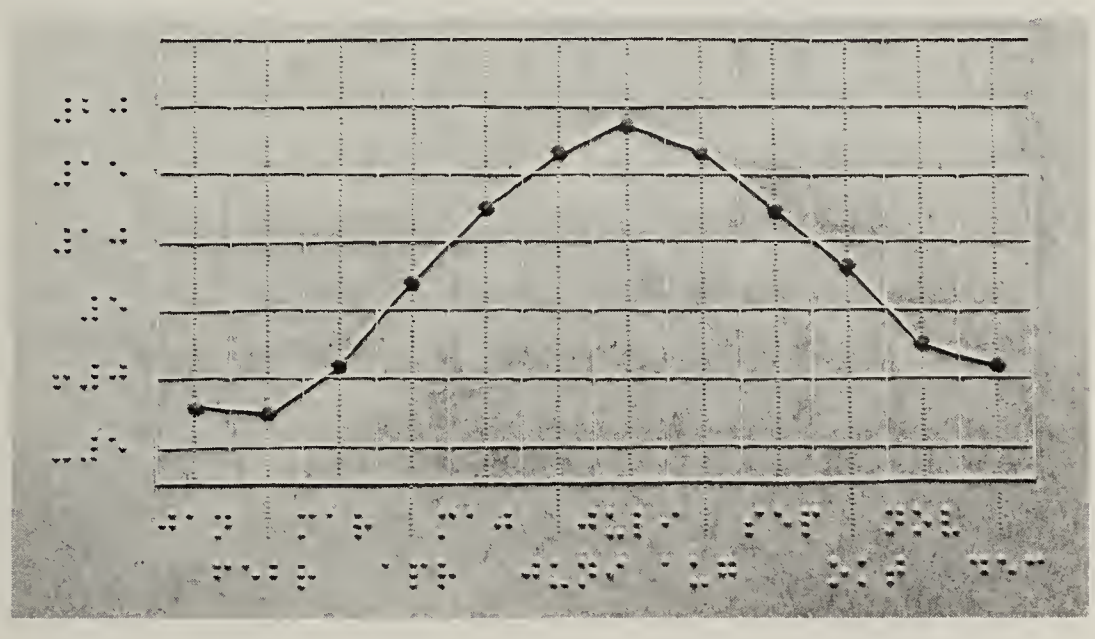
Thread, same thickness as above

Cardboard strip

Thin thread, small knots

Thicker thread, larger knots

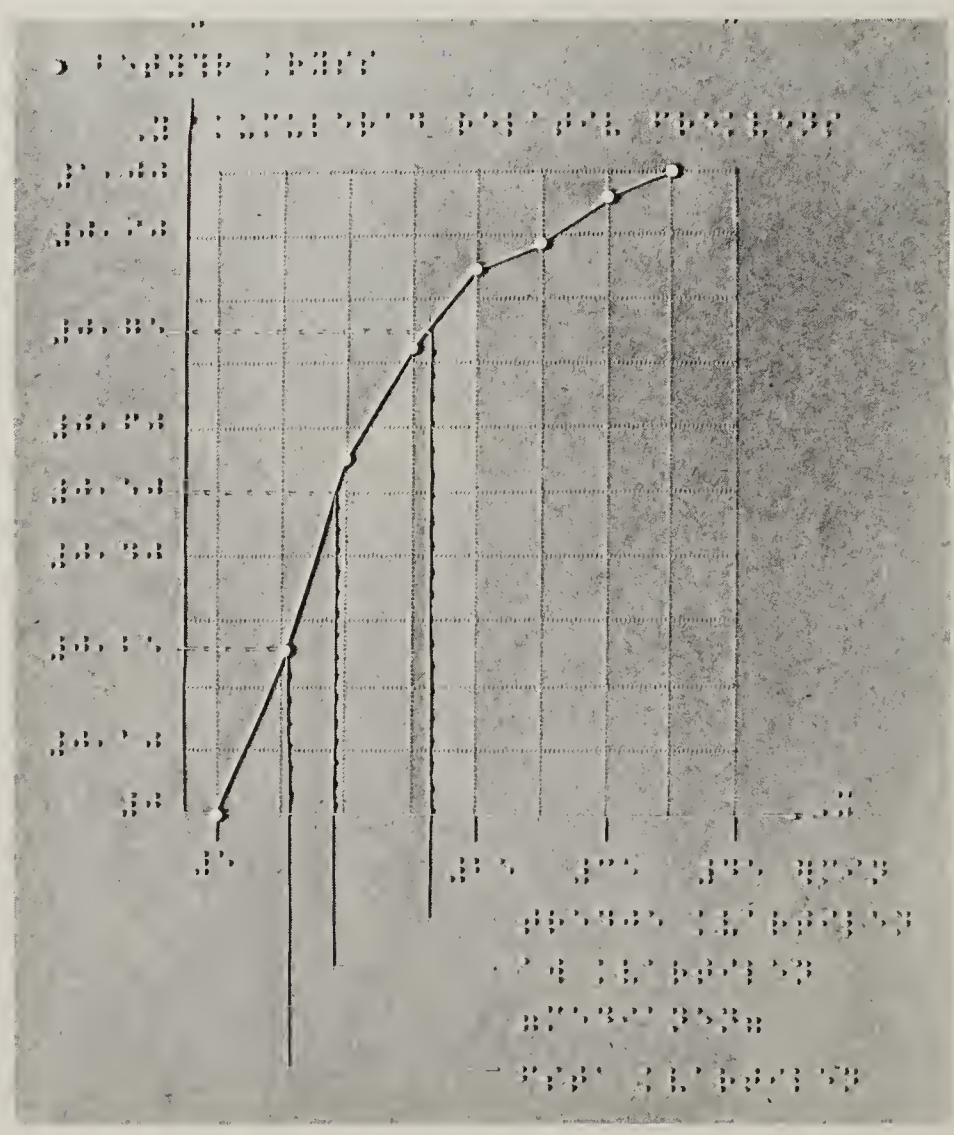
The graph below shows the average monthly temperature in Warsaw, Poland. The dots represent the different months. The temperature range is from 68° F to 16° F (20° C to -9° C). The unusual grid system emphasizes the points of the graph. The grid lines are made of fine preglued thread. Every other vertical line, or half-grid, is an embossed line. These lines also go beyond the horizontal axis to form the tick marks. The cardboard dots are placed only on the embossed lines.



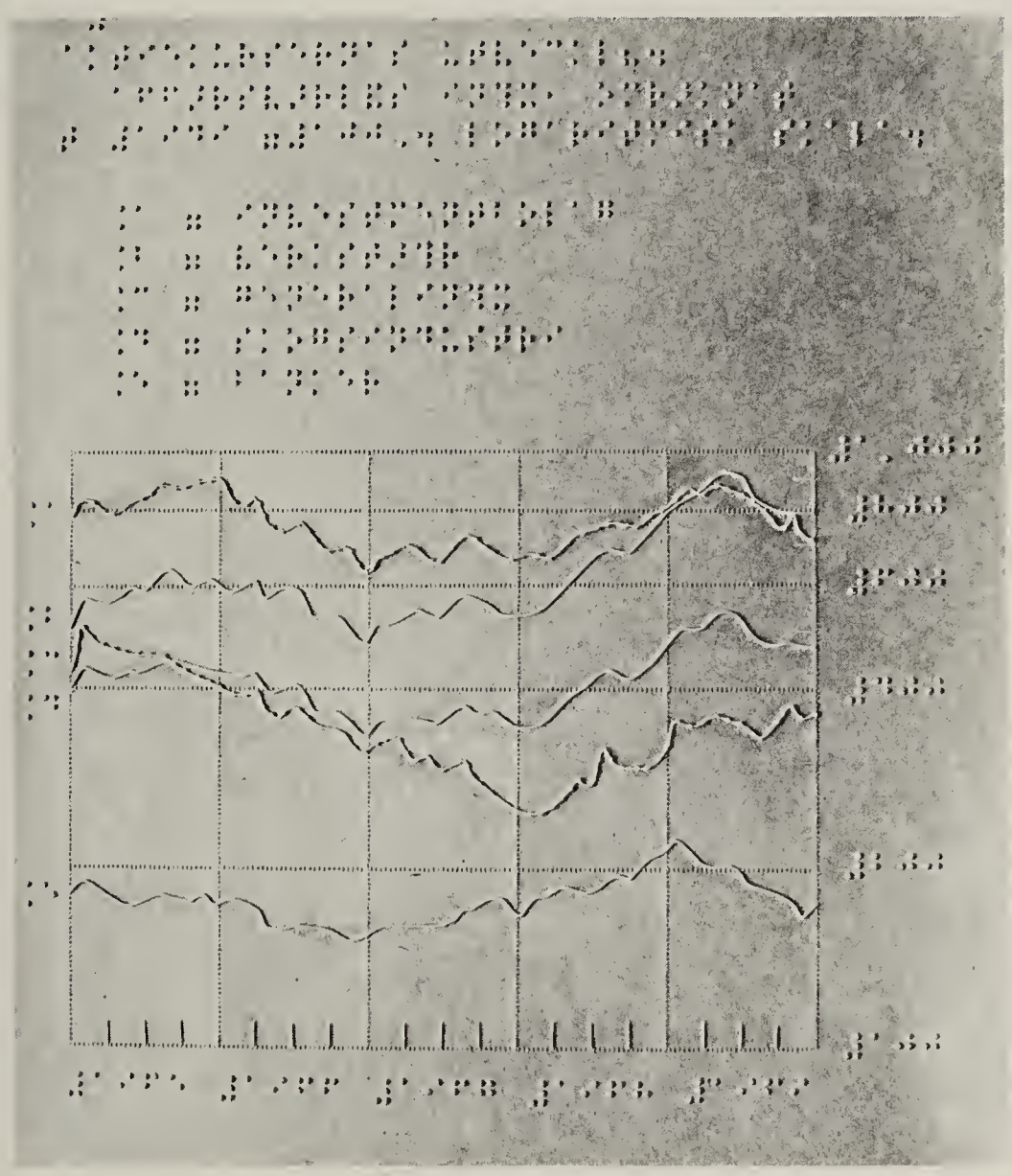
In the graph at the top of the following page, the treatment of the guidelines is unusual; strips of sandpaper and braille paper were used to make a very good low-level texture beneath the lines. That is, however, the only good point about this graph.

The lines are too close together at the beginning of the graph, making it impossible to trace them. An enlargement of this particular area, keyed to a basic graph, would not have helped: The lines would still be too close together. A step-by-step series of graphs should have been used. There should also have been much more of a contrast in the texture, elevation, and size of the material used for the lines.

Instead of written information being placed inside the layout of the graph below, the braille text was placed below the graph and connected to its particular area by a thin, knotted, preglued thread. The graph is uncluttered and easy to understand.



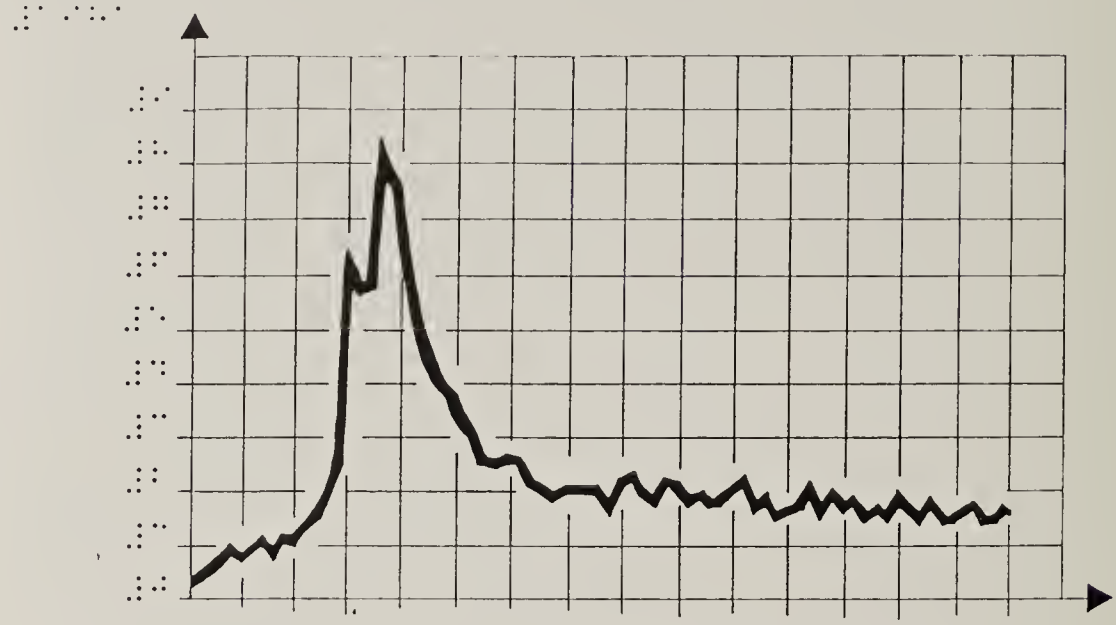
The placement of information on a graph depends on the importance of this information. In the graph below, the first nontext information a reader receives from the graph itself begins on the far left of the layout, which would indicate that this spot is most important.



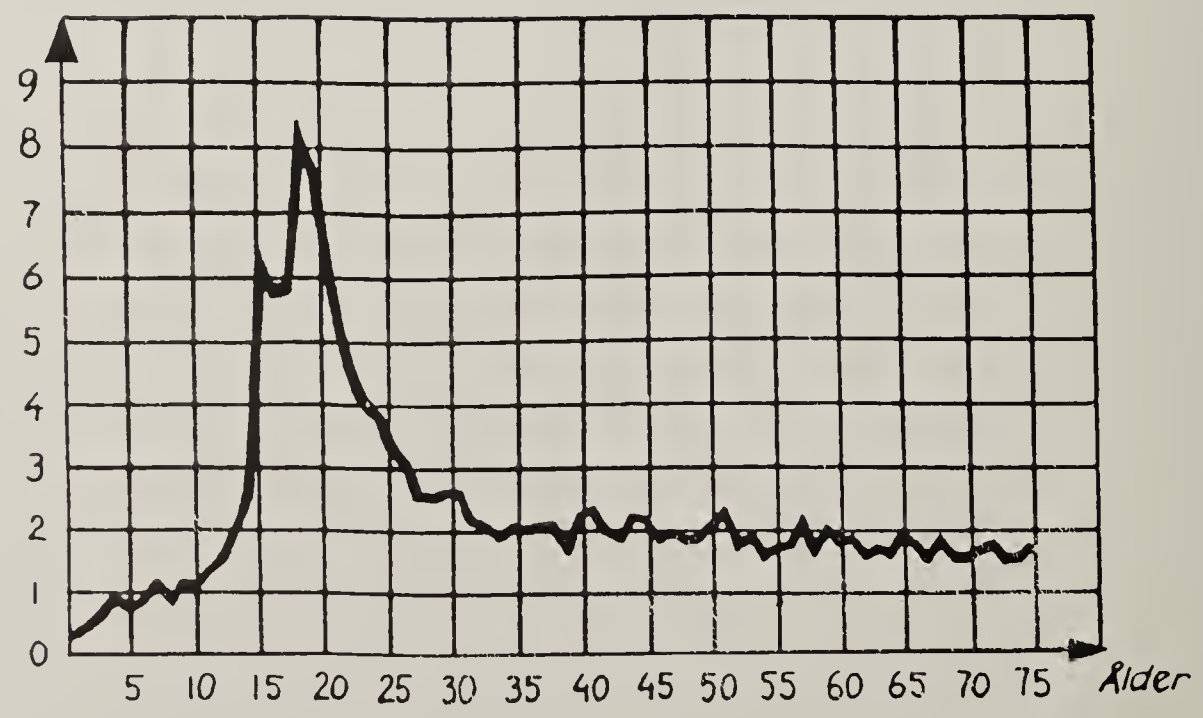
The numbers at the left, on the Y-axis, refer to the names in the key (A=Investment companies, B=Workshops, C=General index, D= Forest industry, E=Banks). This is one way to avoid labeling these lines within the diagram area, an important point, since only two contrasting textures are used for the lines. However, it would have been better if five different textures had been used for the lines and these textures repeated in the key instead of a letter's having been delegated to each concern. The numerical scale has been moved to the far right end of the diagram. Note that the space between horizontal grid lines decreases as the number scale increases from 100 to 1,000. The figures along the X-axis are the years 1965 to 1969.

Of course, identifying numbers would not have been necessary if the producer had used five contrasting lines and repeated these lines beside the names in the key. However, two contrasting textures are easier to find than five, and the only lines that cross each other are of a different texture.

In spite of the grid lines, the microcapsule paper graph shown below is easy to read. The contrast between the grid and the graph line is obvious. All grid lines stop 1/8 in. (3 mm) before the graph line, which is essential.



Compare the graph to the textbook version also shown here below. A direct transfer of the textbook graph to a relief display without any modification would have been difficult to read.



Cartesian Graphs

Cartesian graphs are based on the theories of the 17th-century French philosopher and mathematician René Descartes, who developed a system for indicating graphically the curve of an equation. Cartesian graphs have two axes that bisect each other at right angles. The axes are graduated numerically in both directions from the origin (0), their point of intersection. These graphs also use a system of coordinates, a set of numbers used to specify the location of a point on a line, on a surface, or in space. This set of numbers defines the location of the point in terms of its perpendicular distance from each of the axes. (The coordinate reference system is found in all graphs.)

The grid lines, axes, and tick marks for Cartesian graphs are the same as those already described for the other types of graphs. The axes should be obvious to the finger, but they should not dominate the graph so much that the actual purpose of the graph is lost to the reader.

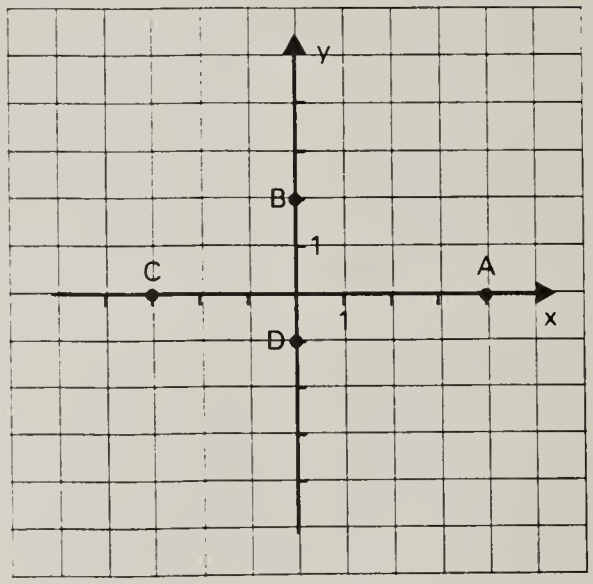
A grid system may or may not be included in the printed graph. If it has been left out in the original graph, then it is not necessary to include it in the relief display, unless you think that the reader needs this aid.

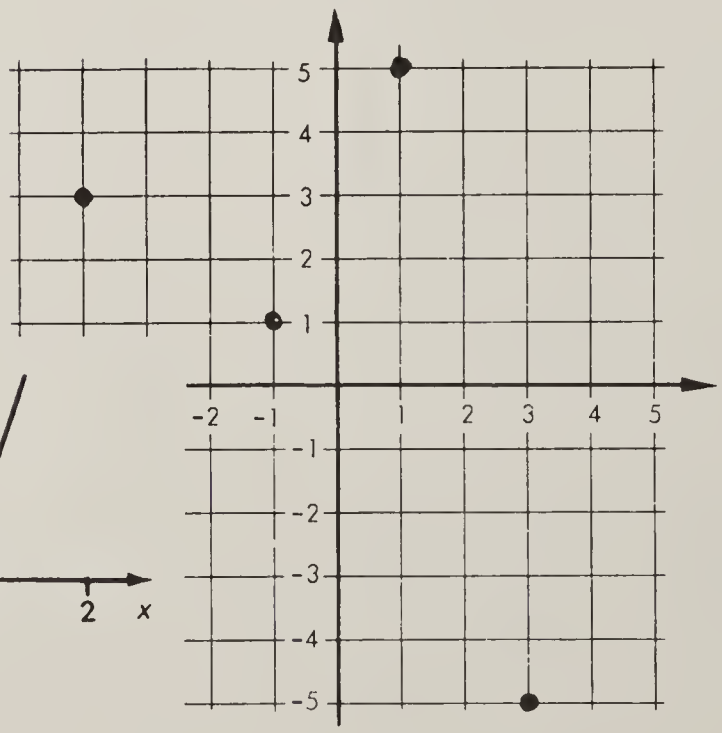
The lines of the grid are important. They should be a quiet but obvious help to the reader. They should be straight, evenly spaced, sharp, and thin or light in character, and they should not vie with the points, curves, or axes for attention. Their purpose is to show the position of the points on the graph, not to form a jungle of lines that will disturb fingers that are tracking a line. Following are several examples of the use of coordinates in Cartesian graphs.

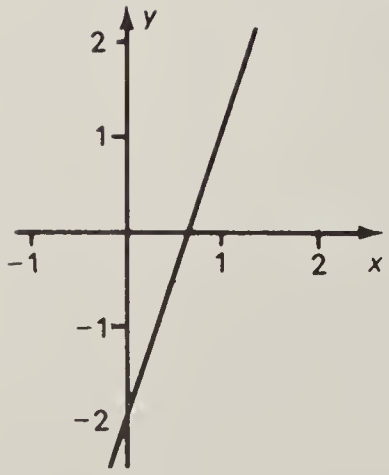
For the set of graphs shown at the top of the next page, the coordinates for point A are 4 and 0; for B, 0 and 2; for C, -3 and 0; and for D, 0 and -1.

Should numbers be placed to the right or the left, above or below the axes? The placement of numbers along the vertical Y-axis can be on the left or right side of the axis, as shown in the various graphs on the following page. The numbers along the horizontal X-axis are always placed below the axis.

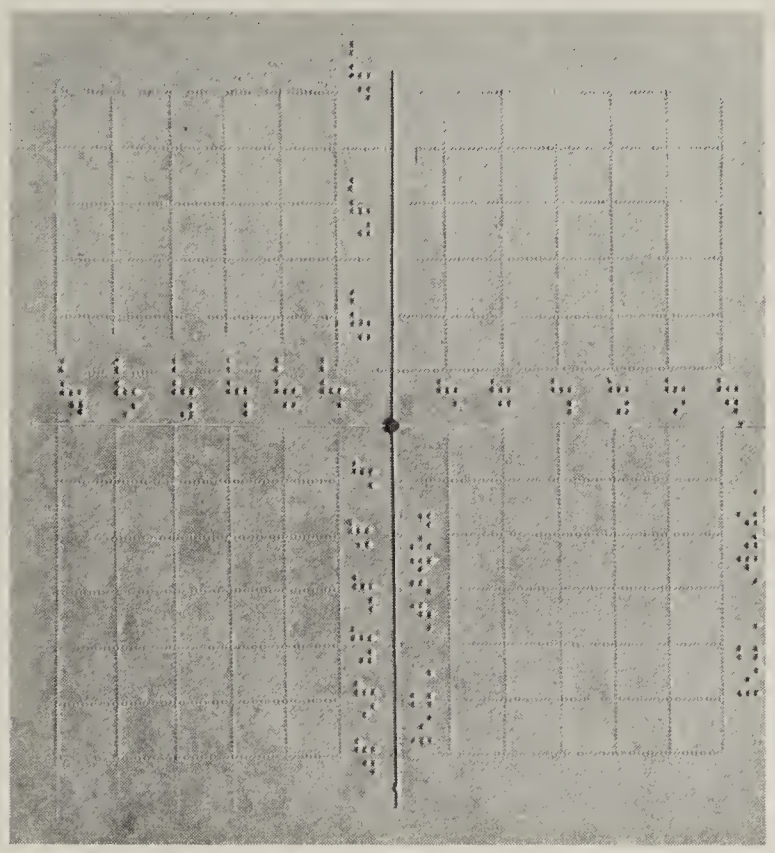
y
5
4
3
2
origin
1
−5 −4 −3 −2 −1 1 2 3 4 5 x
−1
−2
−3
−4
−5


y
B
1
C
A
x
1
D

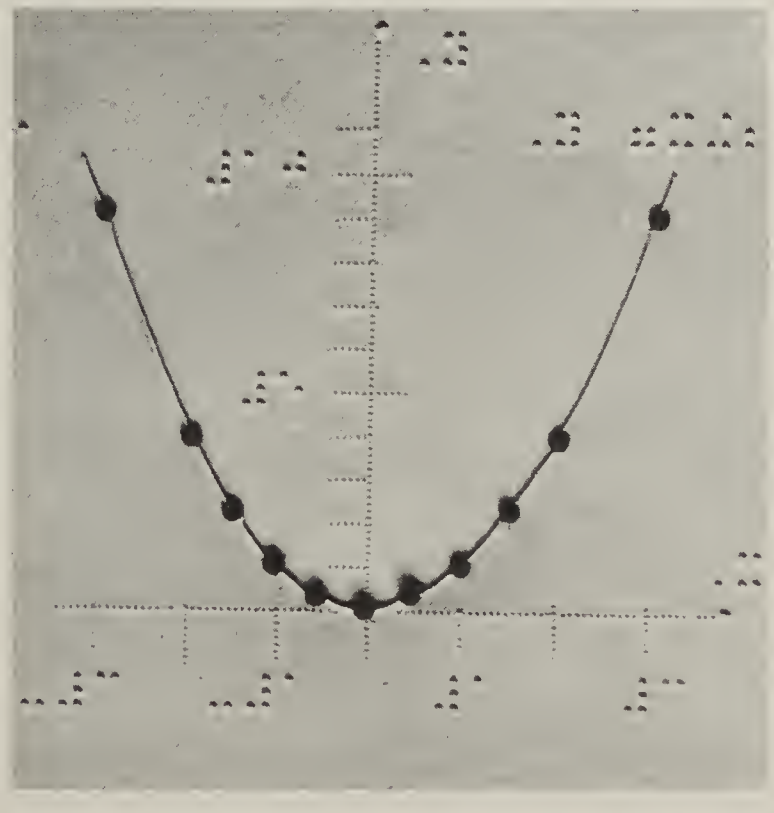

5
4
3
2
1
-2 -1 1 2 3 4 5
-1
-2
-3
-4
-5


y
2
1
−1 1 2 x
−1
−2

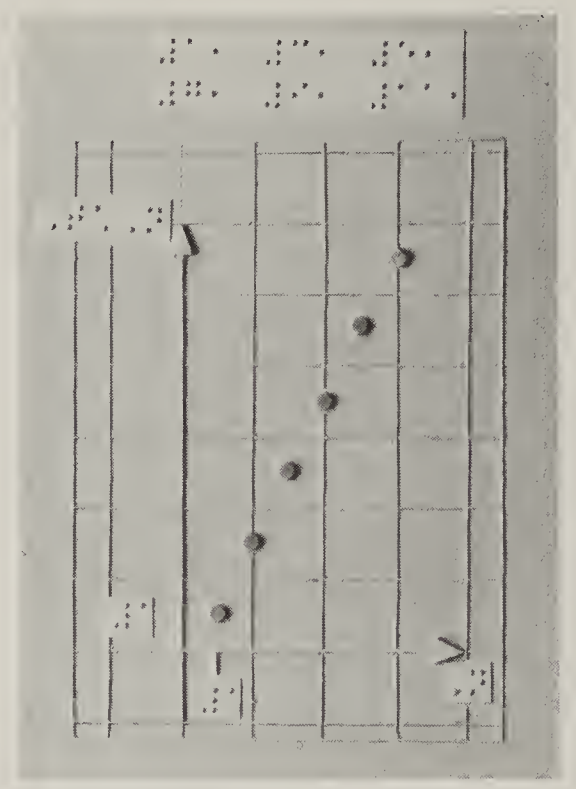
The next graph illustrates the coordinate number system with a grid. The materials used for the axes were thin thread (knot arrows at the end of each axis); for the grid, fine embossed lines made with a spur wheel; and for the dot, hard cardboard (fiberboard).



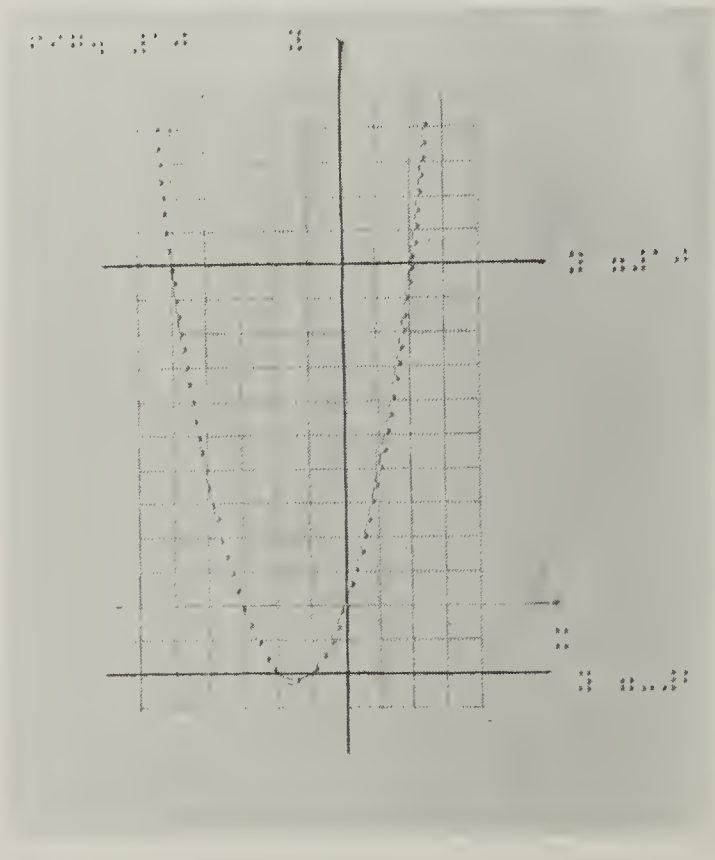
The next example is a Cartesian graph without a grid and showing only part of the two axes. The axes and tick marks were embossed with a fine spur wheel. The arrow symbol is a jumbo dot made with a correction tong. The dots were hand punched out of fiberboard, and the lines were made with heavy thread.



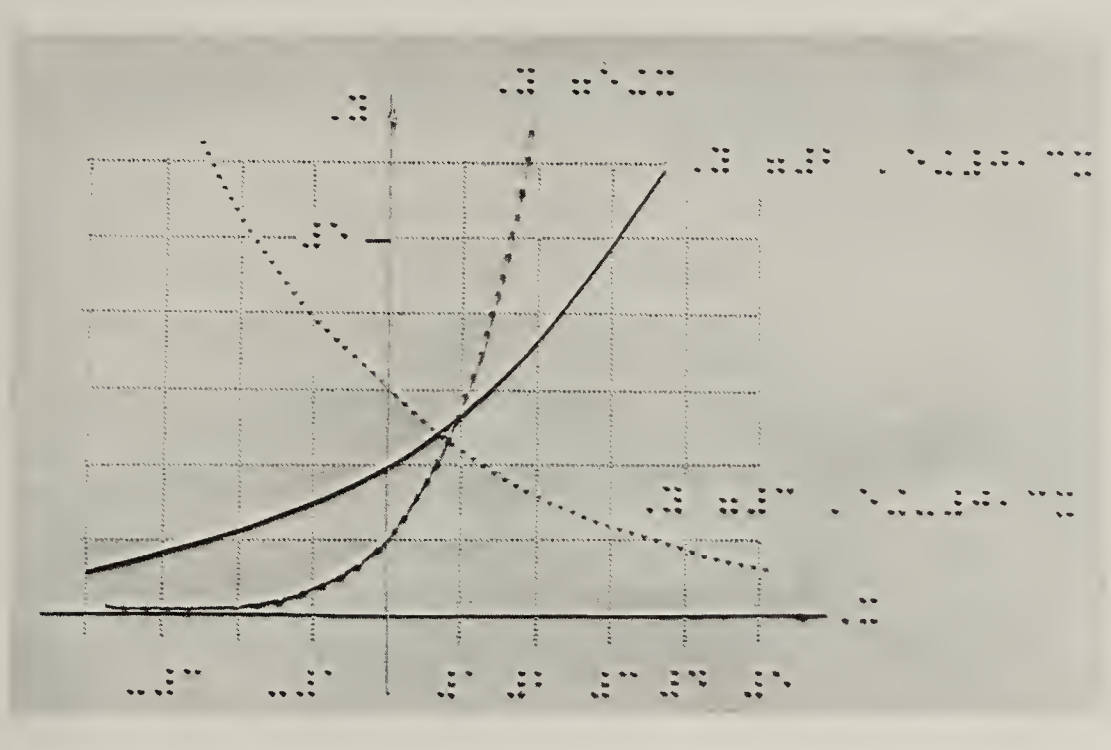
In the section of a Cartesian graph shown below, the number 1 was placed on both the X- and Y-axes. The axes and tick marks were made with heavy thread; the grid, with fine thread; and the dots, with hand-punched fiberboard.



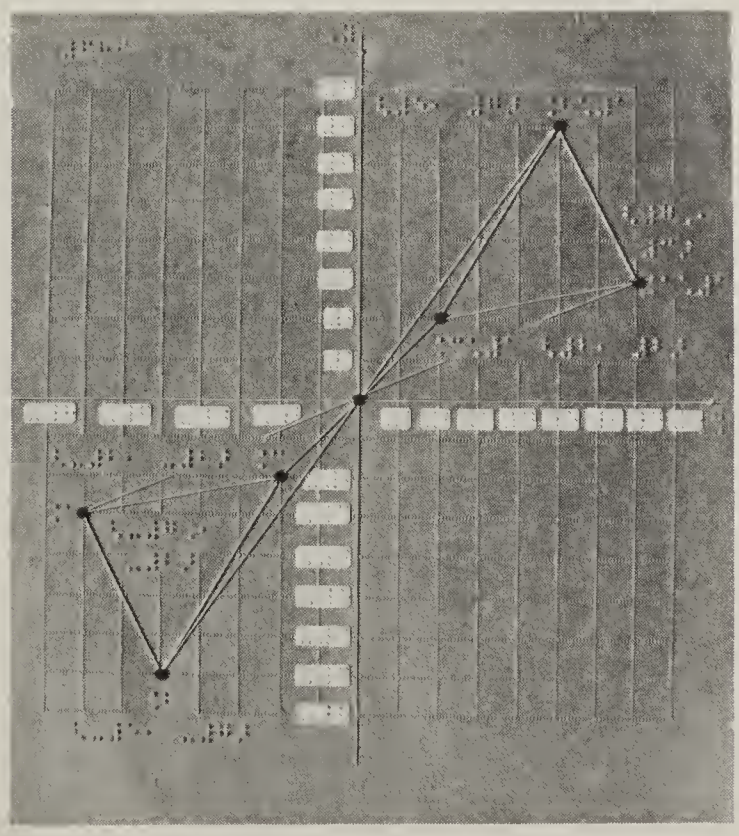
The following graph has no coordinating numbers or obvious tick marks. The axes were made with heavy thread. The arrows were knotted. The grid was finely embossed, and the curve was done with embossed dots made with a standard-braille correction tong. Lines were made with a sewing machine to emphasize two points: Y = 10 and Y = -2.



The next graph exemplifies a good choice of contrasting textures. The axes and tick marks were made from thin thread, and the grid was finely embossed with a spur wheel. The solid line is of heavy carpet thread, and the thin dotted line was embossed with a coarse spur wheel. The heavy dotted line is of the same thread as the axes, evenly knotted.



The graph that follows is a close copy of the textbook illustration, which has printed text crossing the lines that connect the dots. In such a case, do not be bound to the printed layout. This technique, transferred to a relief display, makes line tracking difficult for blind readers because they lose the line within the brailled area.



The dots are already labeled A, B, C, A, B, C. The numbers in parentheses indicate where these points are within the coordinate number system (B = -5, -7, C = -2, -2, and so on). These numbers could be moved to a key. The area then becomes less cluttered, and the lines are not interrupted. Note that the labels were glued in place to give emphasis to the numbers.

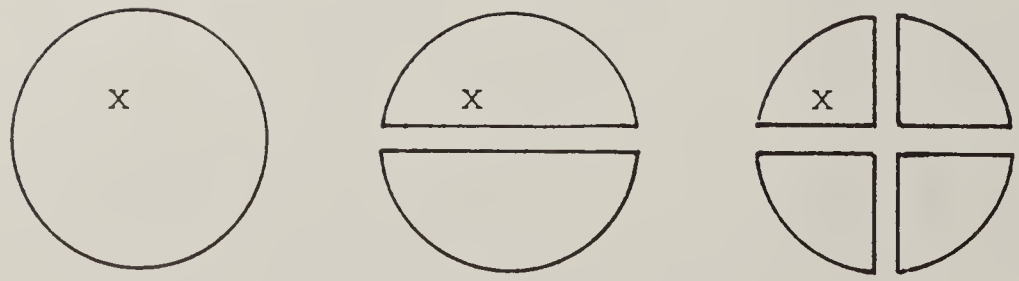
Circle Diagrams

The circle appears very often in the teaching of mathematics, from fractions to advanced geometry. Along with the clock, the circle is an ideal aid for discussing fractions and percentages. For young readers, it can easily be related to an orange, an apple, or a pie that is divided into different parts before being eaten. Brightly colored textbook illustrations of fruits, vegetables, and balls can be translated into a coded symbol—the circle (see "Coded Symbols," this chapter). Various relief textures act as substitutes for color.

Remember, you should determine if a diagram is necessary in the first place. Many times an illustration done on a raised-line drawing board (see "Raised-Line Drawing Boards," Chapter 2) by the teacher in the classroom will be sufficient to help the blind student to understand the problem. Some teachers underestimate the use of this drawing board and their ability to use it as a teaching aid. Check first before going to the trouble of producing a relief display.

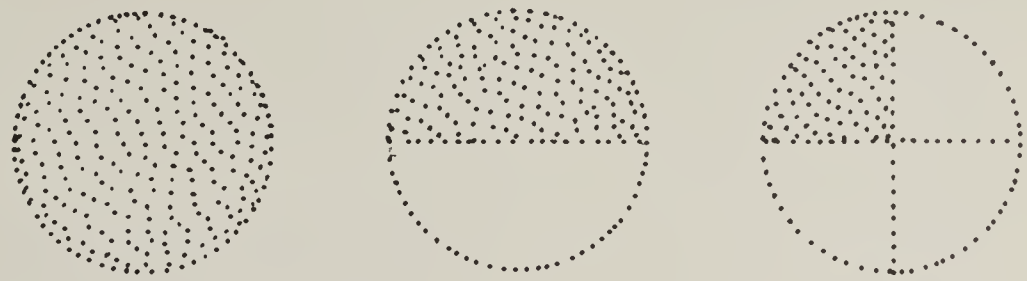
Following are several ways to make circle diagrams.

This paper-on-paper master was made from solid cardboard forms glued to a background. The dotted line indicates where a fine line was made with a spur wheel.

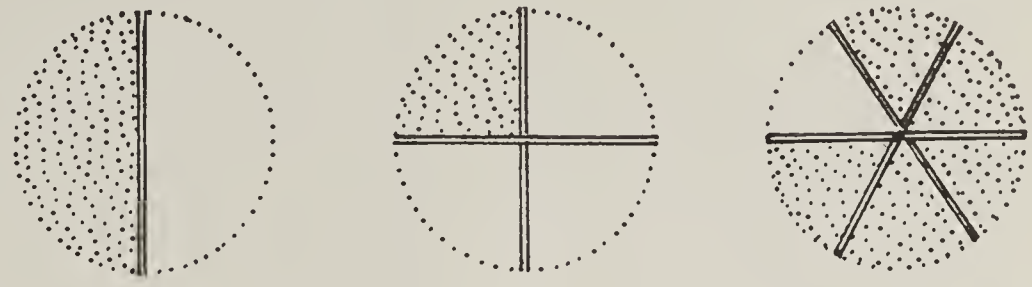


Solid cardboard forms were glued to a background. In one variation, the areas marked with an x can be covered with sandpaper.

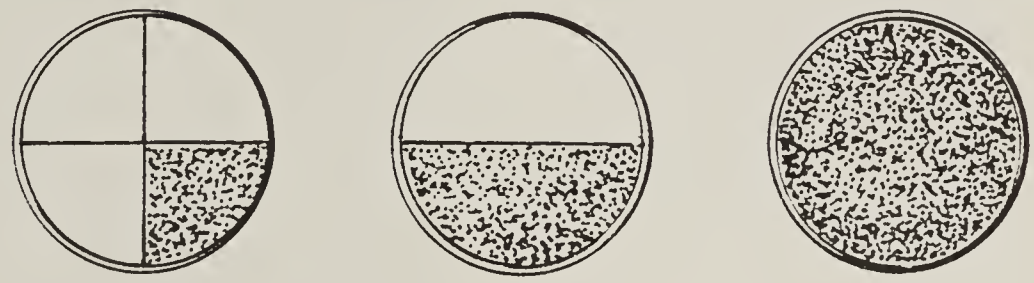
The embossed outline of a circle can vary, depending on the type of spur wheel used. The texture shown here was made by pricking the circle on the back of the paper with a pin.



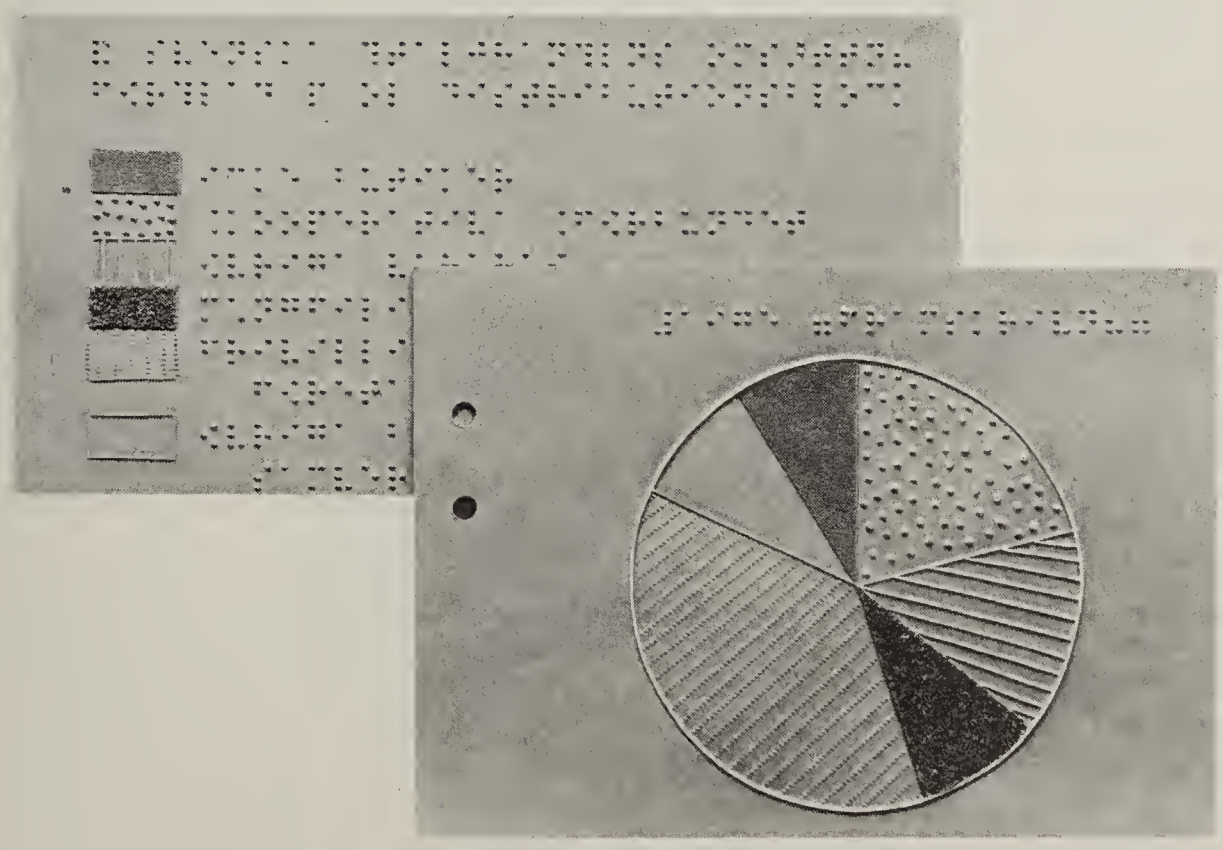
The same technique was used here as in the previous display. The dividing lines are made with coarse thread.



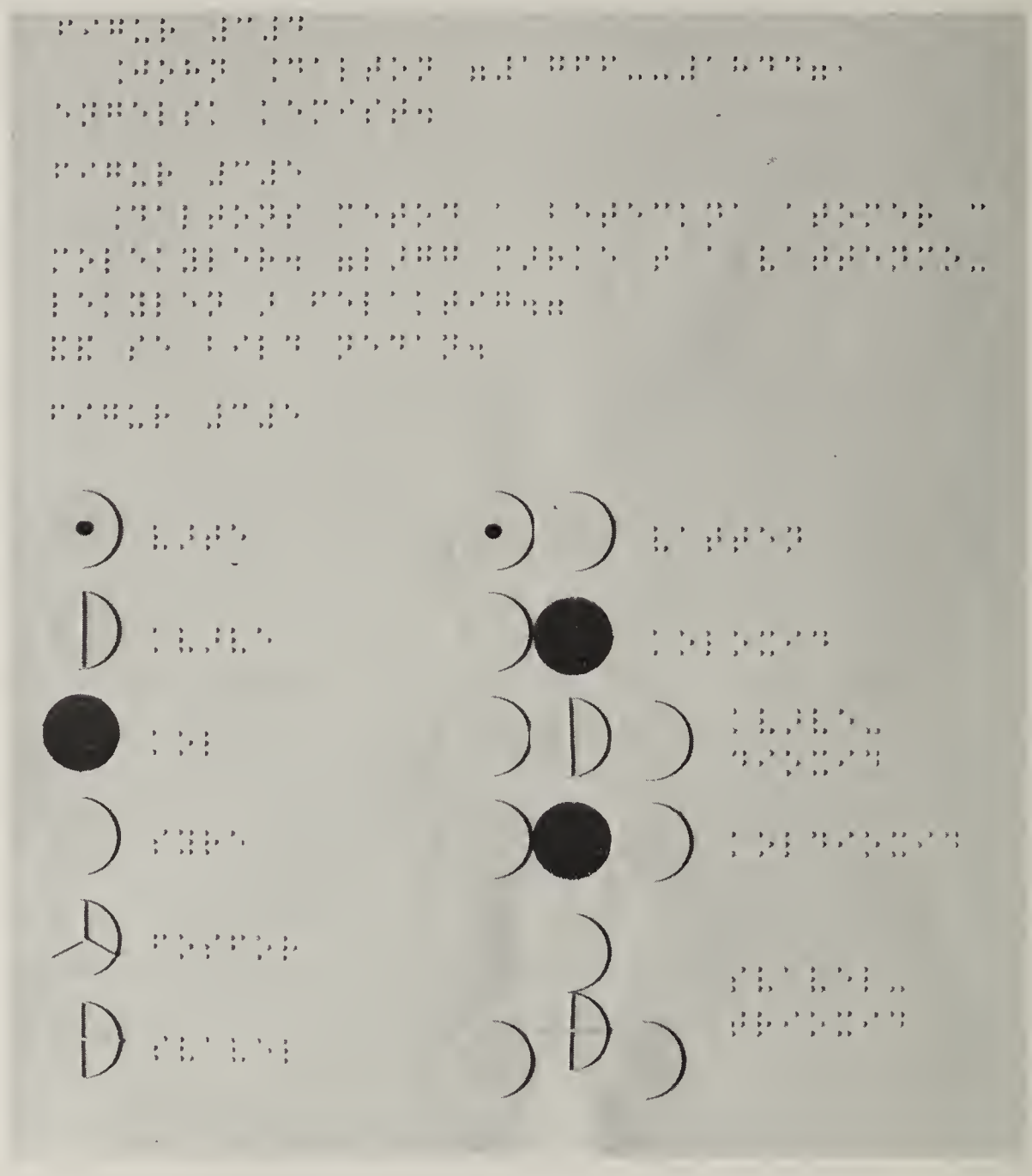
Here the circumference of the circle was of coarse thread. Fine sandpaper was used to fill in the desired areas. The dividing lines were made of the same or thinner thread.



The amount of information in the circle diagram below required the use of several different textures. From top to bottom in the key, these are: fine sandpaper, dots made with jumbo correction tongs, coarse thread or string, coarse sandpaper, embossed lines made with a spur wheel, and the untextured area of the circle. Textures used in a display must differ enough to the sense of touch that there is no chance of confusing them. This is especially important in a one-elevation relief display.



The tactile graphic master shown below is not a circle diagram display. Its key is shown here to illustrate the usefulness of the divided circle as a symbol.



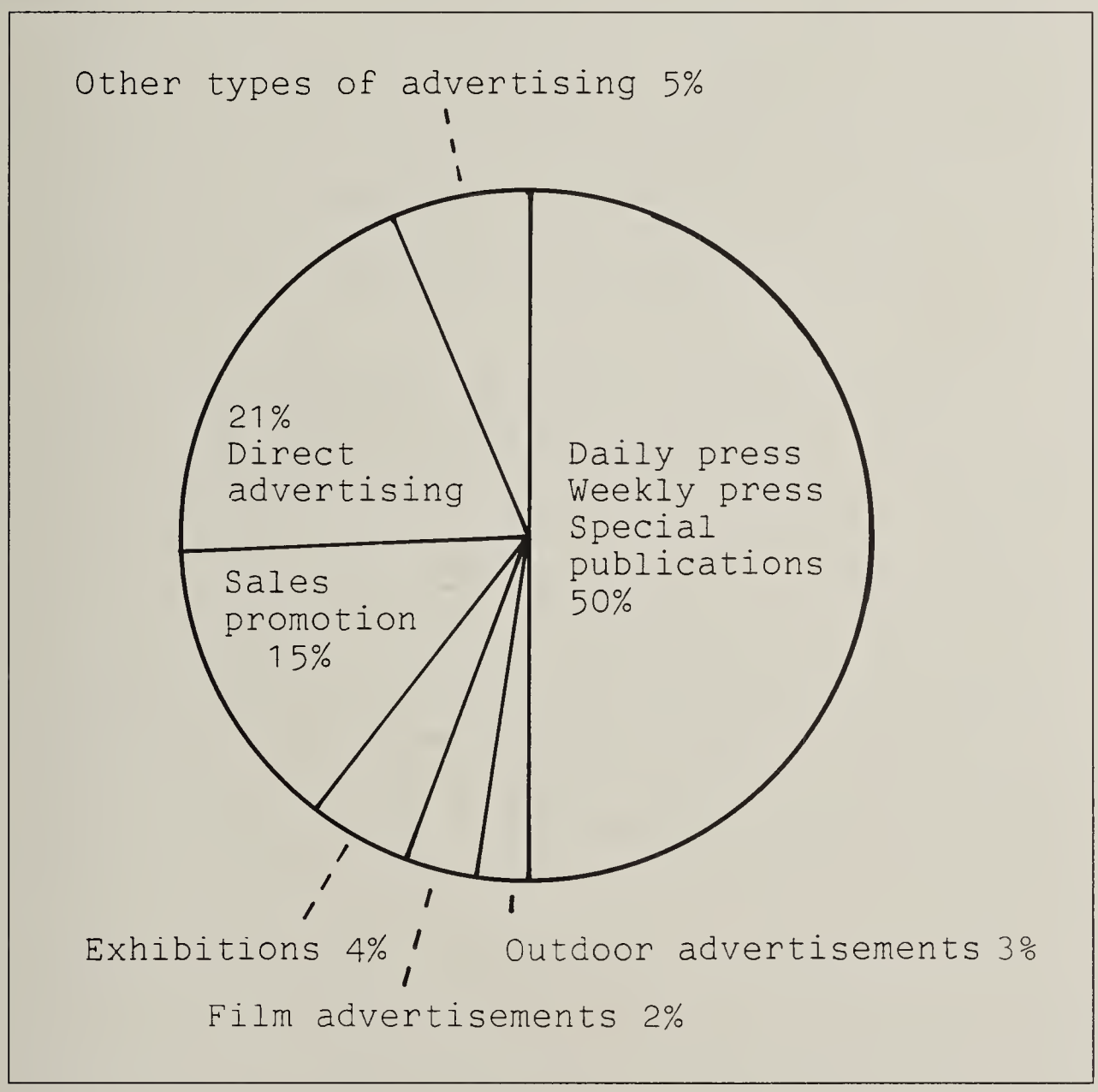
This display is based on a page from a chemistry book. The symbols in the left-hand column are, from top to bottom: hydrogen, nitrogen, carbon, oxygen, phosphorus, and sulphur. The symbols in the right-hand column are, from top to bottom: water, carbon monoxide, nitrogen dioxide, carbon dioxide, and sulphur trioxide.

Percentages can be illustrated by a circle divided into 10 areas around the circumference—each line symbolizing 10 percent (36 degrees). Below is a diagram for an area that shows the percentage of land taken up by fields (62 percent), grain (27 percent), and forest (11 percent).

Labeling a Circle Diagram

The labels on the diagram below (shown in actual printed size) are inconsistently placed. Sighted readers can take in the diagram at a glance—the location of the labels, inside or outside the circle, makes no difference to them. For blind readers, however, this layout is difficult to follow. It would be easier for them to read if the information were gathered in one place.

A key would be the best solution for this diagram. The text within the diagram could be removed from that area, leaving it uncluttered and making the divisions of the circle more prominent.

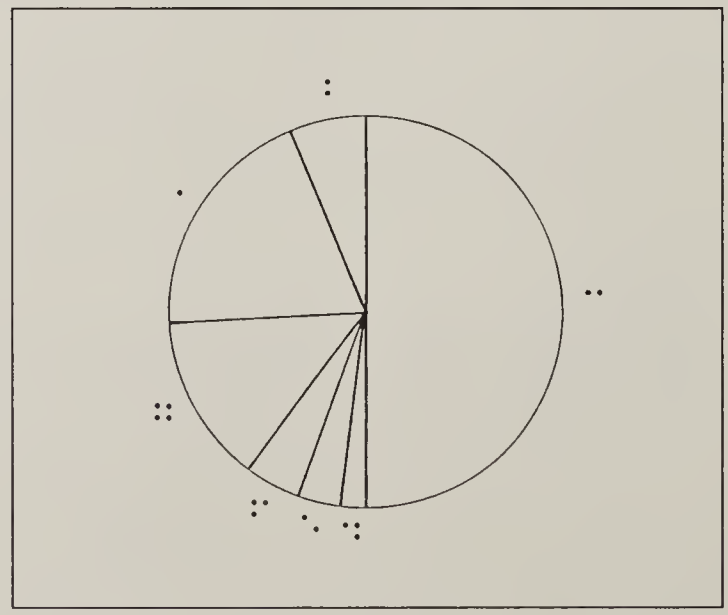


Some producers think that no text should appear within the circumference of a circle diagram and that the information should be placed outside the circle, close to the area to which it relates. If necessary, guidelines should stretch from the information to the particular area.

Each diagram is a case in itself, and what is right for one may not be right for another. Some diagrams are suitable in size and simplicity for labeling areas within their outer boundaries. This technique is successful only if the text or symbols used in these areas do not distract the reader from gaining a clear understanding of the form and divisions of the diagram. If possible, try to place all labels inside or outside a circle diagram. This may necessitate using symbols—letters, numbers, or textured areas that are related to the diagram's information—on the diagram and in an adjoining key. Avoid mixing these three types of symbols in a circle diagram that will have a key. *Note*: Blind readers often understand textured circle diagrams more quickly than those keyed with numbers or letters.

The amount of text decides the layout of the diagram. A braille translation of a diagram's text may make it impossible to use the text within or even near the diagram because of the enlarged size of the text. Text area is limited. The maximum size of a diagram is dictated by the size of the page in the braille textbook.

The following diagram, reduced 45 percent from the printed version in the immediately preceding illustration, does not have room on the inside or outside of several of its sections for more than one braille letter. The choice of single letters related to the diagram's information was made impossible by the repetition of two of the letters—D and O—in the list of facts presented. (The first one or two letters of a word, phrase, or sentence in a diagram are often used as symbols for the diagram and its related information in a key.) Unrelated letters—A through G—were therefore chosen.

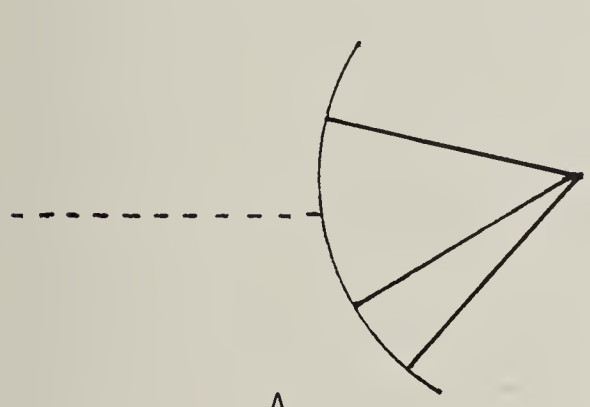


Connecting Lines

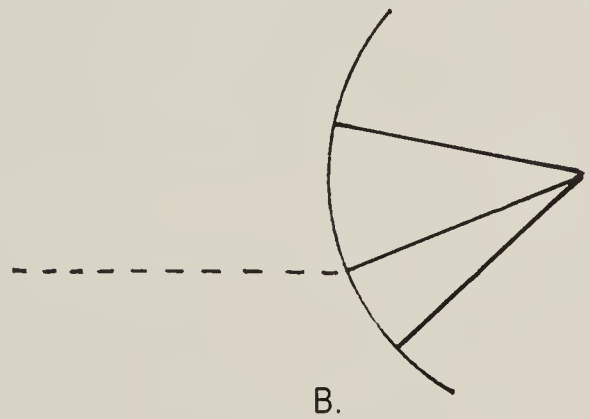
Be sparing in the use of connecting lines that run from a label outside the diagram to the section within the diagram that the label represents, except when the sections of a diagram are too narrow or small to allow placement of symbols near these sections. These lines tend to become a part of the actual form, an extension of a division line, and can lead to misunderstanding.

If you use connecting lines, be sure that they feel different from any other line in the display. This will help reduce the likelihood that the reader will confuse part of the diagram with a reading aid.

Connecting lines touching the circle's circumference should lead from the center of the section to which they pertain to the information label for that section (see A), not from the division line of that section (see B). Line B may confuse the reader as to which section the information belongs.



A.



B.

A gap of 1/8 in. (3 mm) should exist between the circle's circumference and the connecting line in one-elevation displays—those that are embossed or made on microcapsule paper. This gap enables the reader's fingers to adjust from one element to another.

Enlarging a Diagram

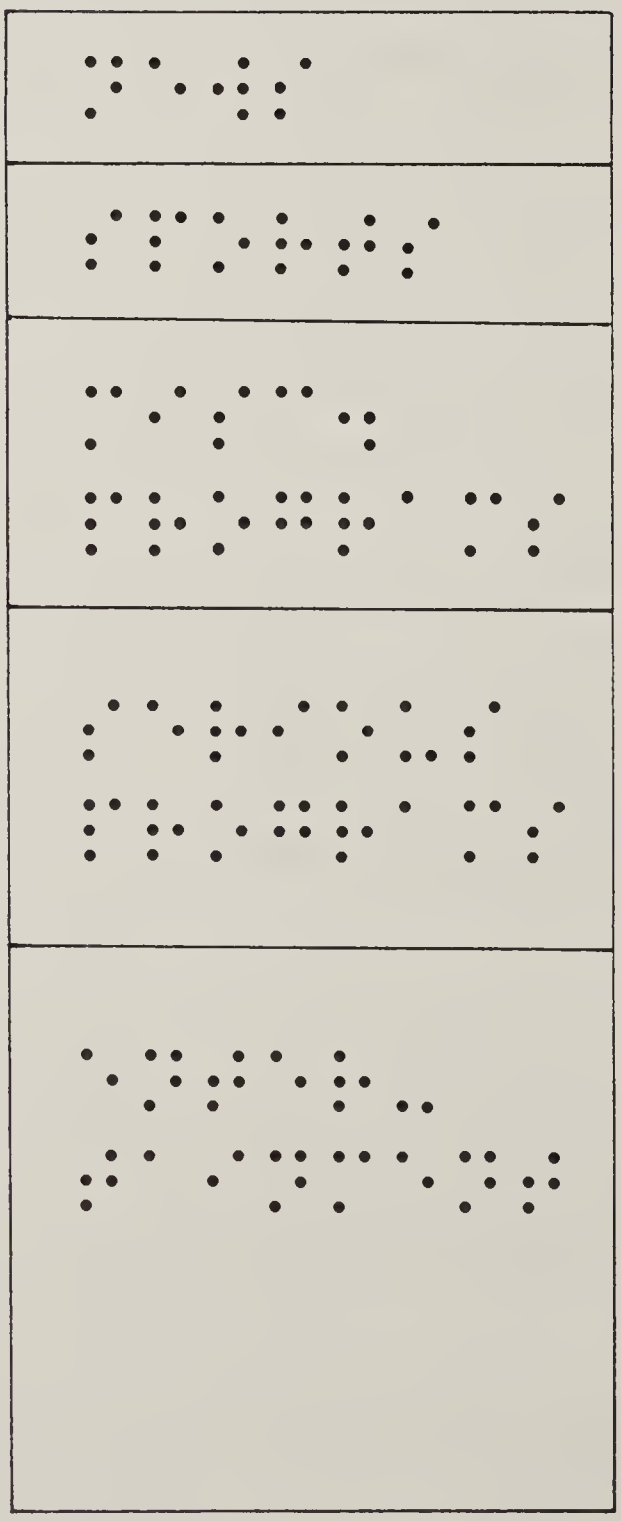
Enlarging a circle to accommodate the necessary information is not always the best way to make a display. Readers may lose the overall idea of the diagram in a large display and may have to go back over the diagram several times to understand its content. Try to do the following:

- Break down the information and present it in several circle diagrams.

- Transpose the information into textures or symbols and use a key.
- Present two circle diagrams in place of a complicated diagram, one diagram without text and the other with text or symbols. Using two diagrams will facilitate the formation of a first impression by the reader and allow him or her to become oriented rapidly to the diagram layout without the distraction of the text.

Histograms or Box Graphs

A histogram is a figure made up of continuous rectangles whose widths are in proportion to the group of things to be considered and whose areas are proportional to the frequencies of these things. Some examples follow.



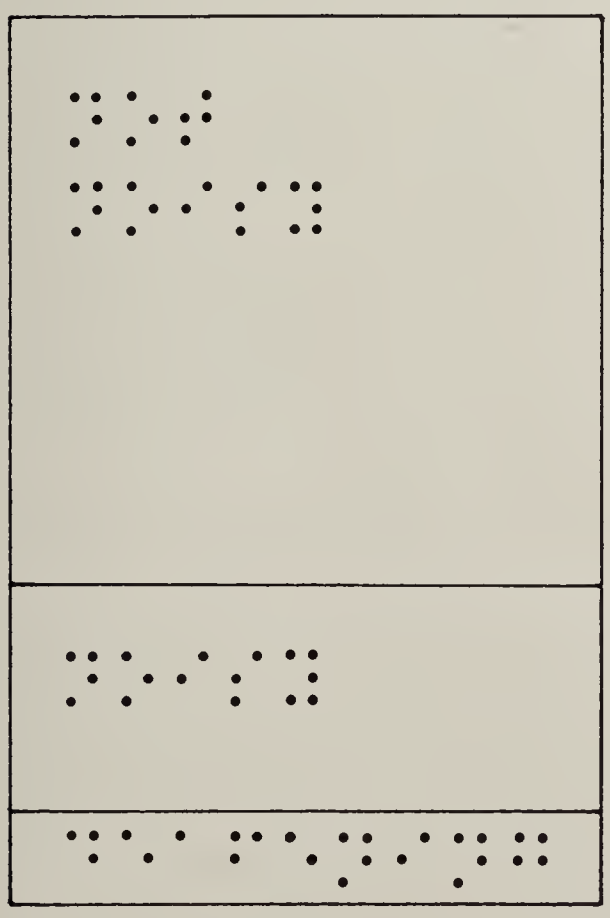
1. The histogram presented here shows the yearly content of programs for a television channel (Statistiska Centralbyrån, 1976). The type of program and hours for each type were as follows: news—442 hours; serious programs—1,009 hours; entertainment—1,693 hours; sports—481 hours; and miscellaneous—827 hours. The histogram is a graphic representation of these numbers. To determine the overall length of the figure needed to fit the size of the page and the size of the braille text, I divided the total amount of hours, 4,452, by 100 (44.52), by 200 (22.26), and by 300 (14.84) to find a suitable length, since a figure with 4,452 units would be too large. Dividing 4,452 by 300 results in 14.84, which rounds off to 15 units. For a unit measure, I chose centimeters. The size of each section was determined in the same way (that is, for serious programs, for example, 1,009 was divided by 300, the result being 3.4 units).

2. The histogram below and a circle diagram were made on the basis of the same information about answers given by 6,000 people to the question, "Is it noisy where you work?" (Nyman, 1984). Allowing for rounding, 10 percent answered that it was deafening; 25 percent answered that it was constantly noisy; and 64 percent answered that it was not noisy at all.

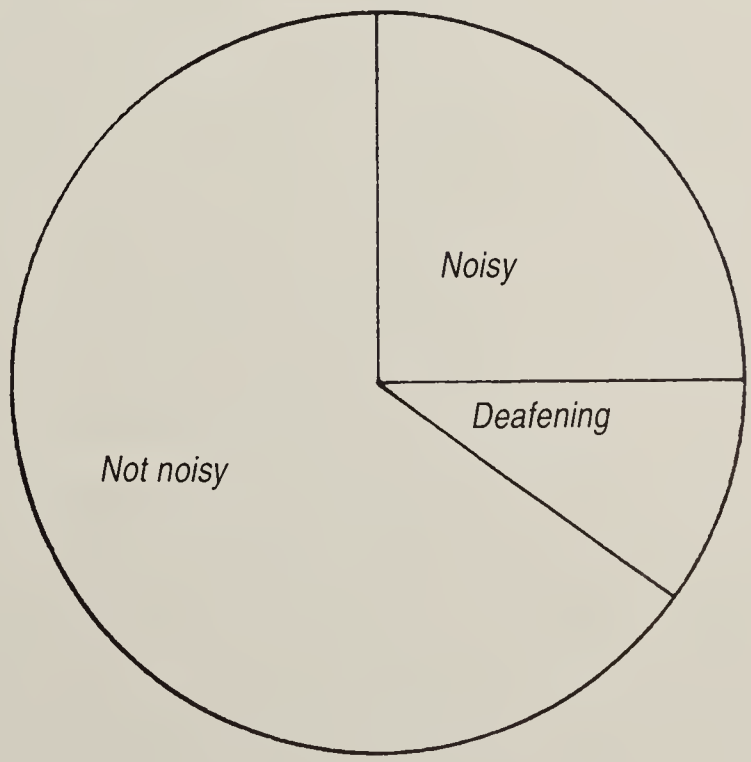
A histogram made to suit information stated in percentages is based on 100 units—the total height of the figure. Each section is a percentage of the total figure: If the section is 25 percent, the height of the section is 25 units. Note that there does not seem to be any rule concerning the location of the largest section of a histogram—at the top or the bottom of the figure.

If there is too much text for the histogram boxes, move the text outside the boxes, or use a symbol in each box and explain its purpose in a key. When making room for the text within the boxes, do not enlarge the diagram so much that the reader will miss the size relationship of the individual sections.

The following formula was used to calculate the angles or sections of the circle diagram that corresponded to the histogram. You can use a similar formula:



360° = complete circle = 100%
360 x .10 (10%) = 36, angle 36°
360 x .64 = 230, angle 230°
360 x .25 = 90, angle 90°



Summary of Guidelines for Producing Graphs and Diagrams

The preceding sections of this chapter have presented a good deal of information. The following principles can be summarized from the material discussed.

1. Carefully read the text that accompanies a graph or diagram.

- Decide if the figure should be produced.
- Determine how it should be produced—with one or several elevations.
- Decide on the changes that must be made when transposing the printed layout to a relief display.
- Check on your readers' ability to read relief material, braille or large print, and black-and-white diagrams. Make material that suits their needs. The form of the inkprint graph or diagram may not be the only solution; consider other possibilities.

2. The amount of information imparted by the diagram dictates the size of the relief display. Seek ways to reduce the figure to its basic information. Keep it as uncluttered as possible. If necessary, use a key and place it on the same page as the diagram or on a facing page. Any irregularities (for example, because there was too little room for the entire length of a number series, every third number is indicated) that may occur in the graph should be explained in the key or in the text preceding the relief figure.
3. If the diagram is broken down into a step-by-step series of illustrations, be sure that each figure is preceded by the number or title of the inkprint diagram, plus an extra letter or number to indicate its position in the series.
4. Diagrams that are bound in a braille book should be placed after the paragraph to which they refer.
5. Make an extra folder or book of diagrams if there are many relief displays. This book should accompany the braille book. The title and catalog numbers on both books should be the same. Be sure that page numbers and figure numbers on the relief displays coincide with those numbers in the textbook and braille book.

6. The greater the contrast between the different elements of a diagram, the easier it is for the reader to understand the meaning of these elements and establish their position in the diagram as a whole. This rule may influence your choice of a medium—a diagram of several elevations or of one elevation.
7. Simplify the display for easy reading. The information content should be the same as the printed material, but the layout and graphic content of the material can be changed by doing the following:

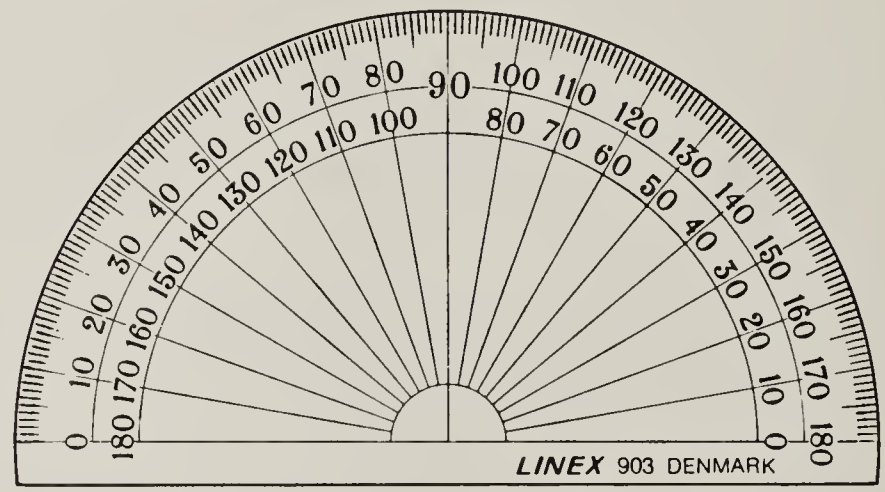
- Move the information from one area to another.
- Change the position of the figure from horizontal to vertical to fit the format of the page.
- Remove unnecessary details.
- Use a key.
- Make two displays, one without text and one with text.
- Make a series of step-by-step illustrations, and add information to each step.
- Eliminate perspective.
- Emphasize certain elements to increase the possibilities of identification and tracking.

8. It is not necessary to follow the placement of the printed text in the relief display. A braille text requires more space and must be placed where it will not interfere with the actual diagram. Rearrange the layout to obtain the simplest way to follow lines, symbols, and text. Try to keep all text going in the same direction; do not place some text in a vertical position and some in a horizontal position in the same display.
9. Each diagram represents an individual problem; the solution to one display may not be the answer to the next. Lines that were acceptable together in one diagram may not be so again, depending on the type of information to be presented, the background of the display (grids and guidelines), or the surrounding information. Make the most important information the dominant line or area in the display.
10. Before you make graphs and diagrams, review the sections "Symbols: General Information," "Point Symbols," and "Areal Symbols" (Chapter 6); "Labels" (Chapters 4 and 6); "Key or

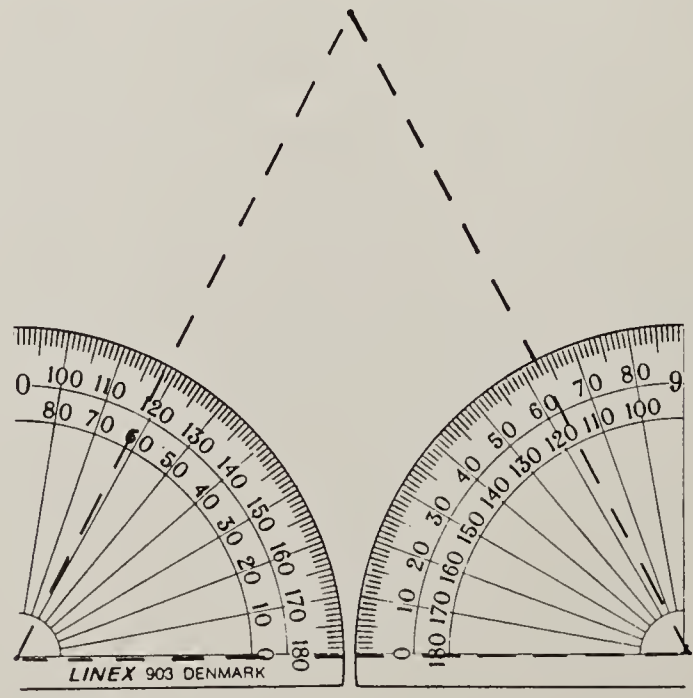
Legend" (Chapters 4 and 6); "Perspective" (Chapter 4); "Arrows" (Chapter 4); "Enlargements and Reductions" (Chapter 7); and "Microcapsule Paper" (Chapter 2).

ANGLES AND TRIANGLES

You, the producer, will seldom be called upon to determine the size of angles or to draw triangles that are not printed in a textbook. However, to be able to check the size of the angles that you make in a relief display, you will need a protractor, a simple, transparent plastic circle or semicircle used for measuring or drawing angles on paper. Semicircular protractors measure angles from 0 degrees to 180 degrees. They have both an inner and an outer number scale to facilitate measuring angles within a closed-plane figure.



Students are often asked to measure the angles in a textbook. Therefore, angles reproduced in a relief display should be correct. Place the center point of the protractor at the vertex or point of the angle and the 0 degree mark on one leg of the angle, as shown below. The size of the angle is determined by the point where the second leg of the angle crosses the number scale on the protractor.



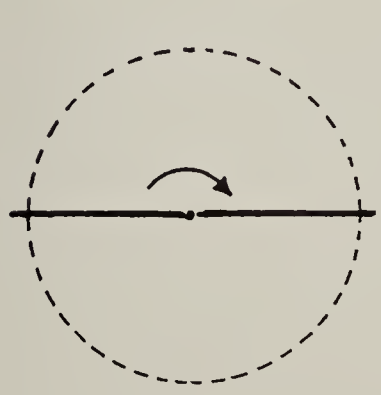
How to Construct Angles

To construct an angle, begin by drawing a line. Place the protractor's center point at one end of the line. Make a mark at the desired degree on the protractor's numerical scale. Draw a line from the end of the first line—which was at the protractor's center point—to this mark.

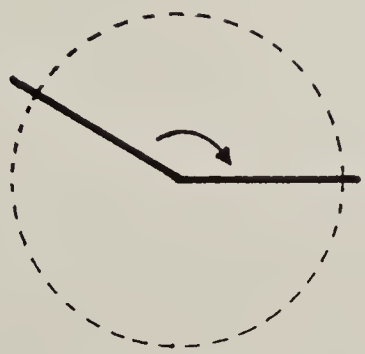
Be sure that the angles you produce in relief are correct and clearly made, so that blind readers will be able to get the same information as their sighted classmates when they measure the angles with a protractor. The legs of the angle must be long enough to be felt beyond the area of the protractor. Otherwise, the students will not be able to determine the number of degrees between the two legs. An average protractor for blind students has a radius of approximately 3 in. (7.6 cm). Therefore, the legs of the angle should be slightly longer than that size. Protractors are available from Deutsche Blindenstudienanstalt e.V. and Howe Press (see "Sources of Materials and Equipment," Appendix 3).

A protractor with braille markings for blind students.

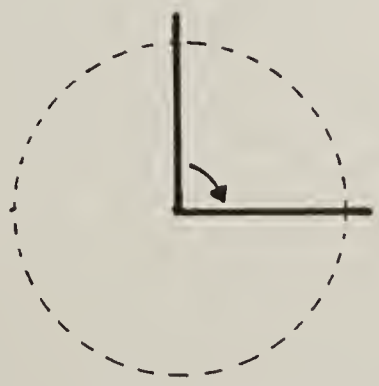
Types of Angles



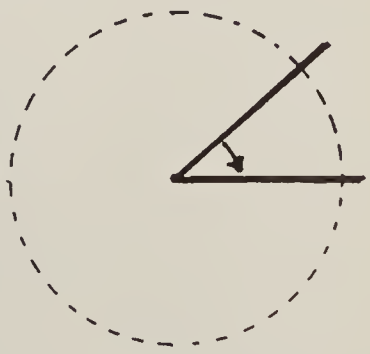
0° to 180°



Obtuse angle
90° to 180°



Right angle
90°

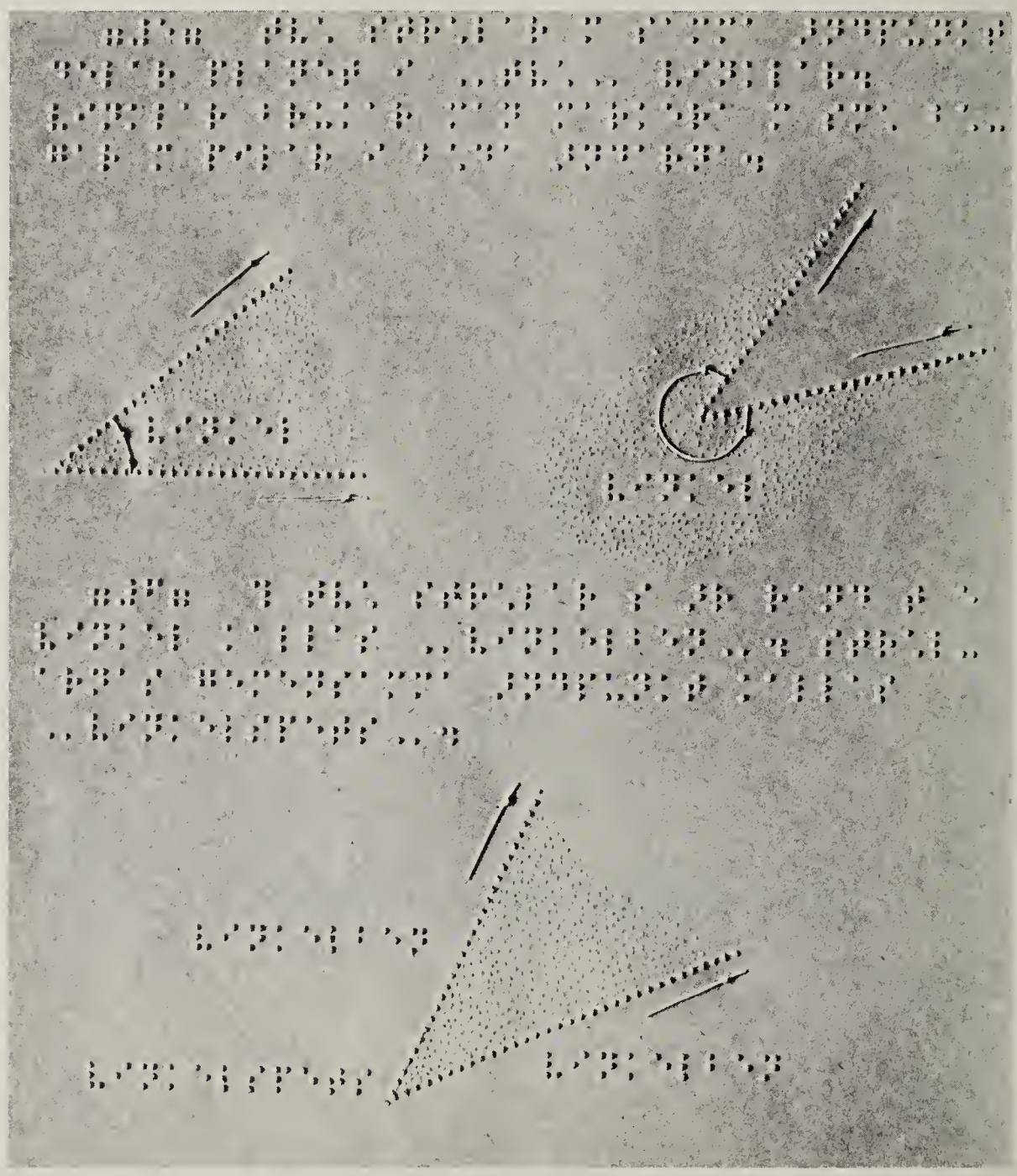


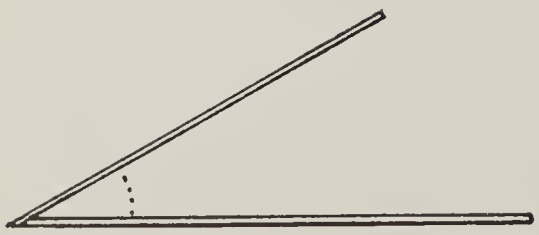
Acute angle
0° to 90°

Angles in Relief Displays

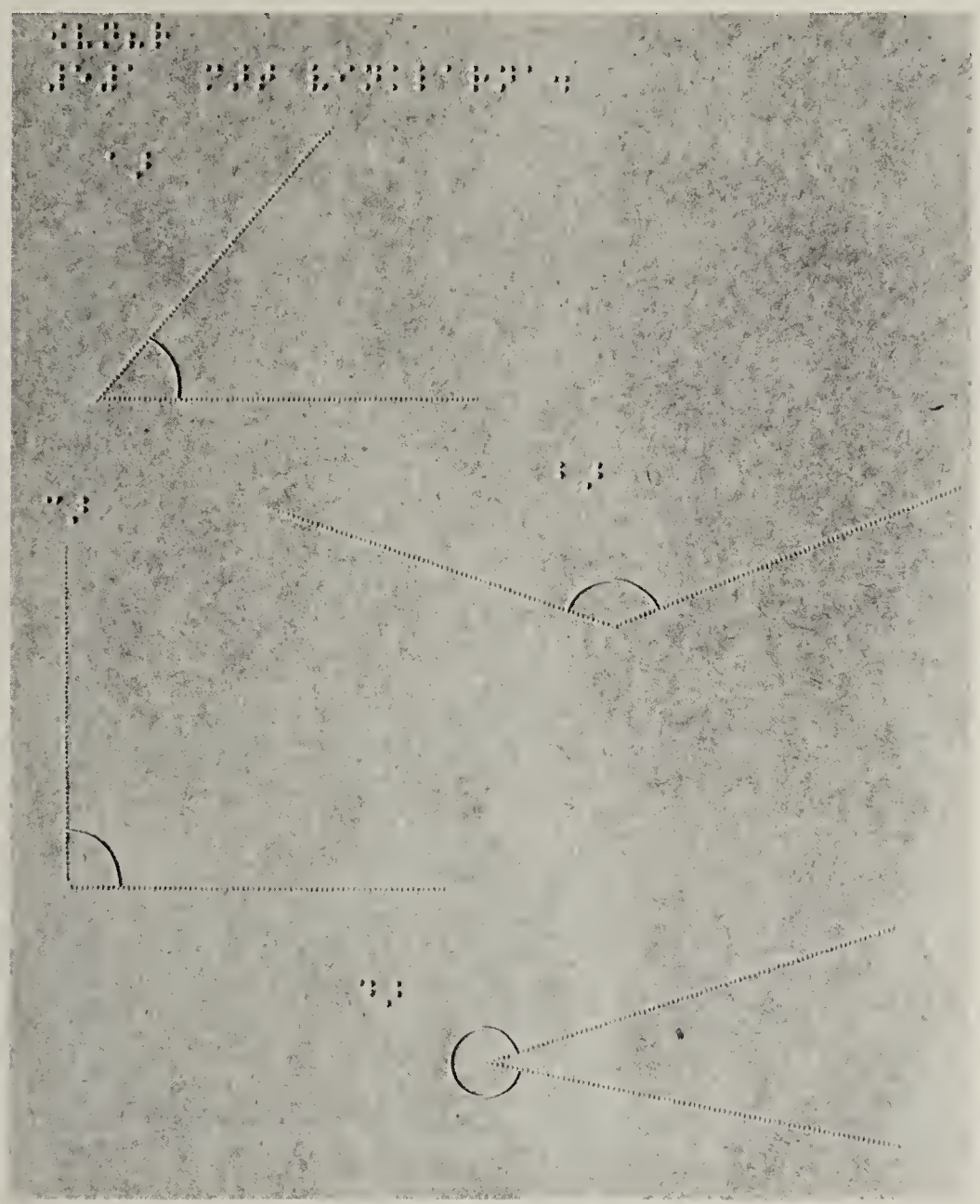
Following are several examples of techniques for making angles in relief displays.

In the example shown below, the angles were embossed with a spur wheel, and the angle indicators and arrows were made of thread. The dotted area inside or outside of the angles was made by pricking the heavy paper with a pin on the reverse side of the page.

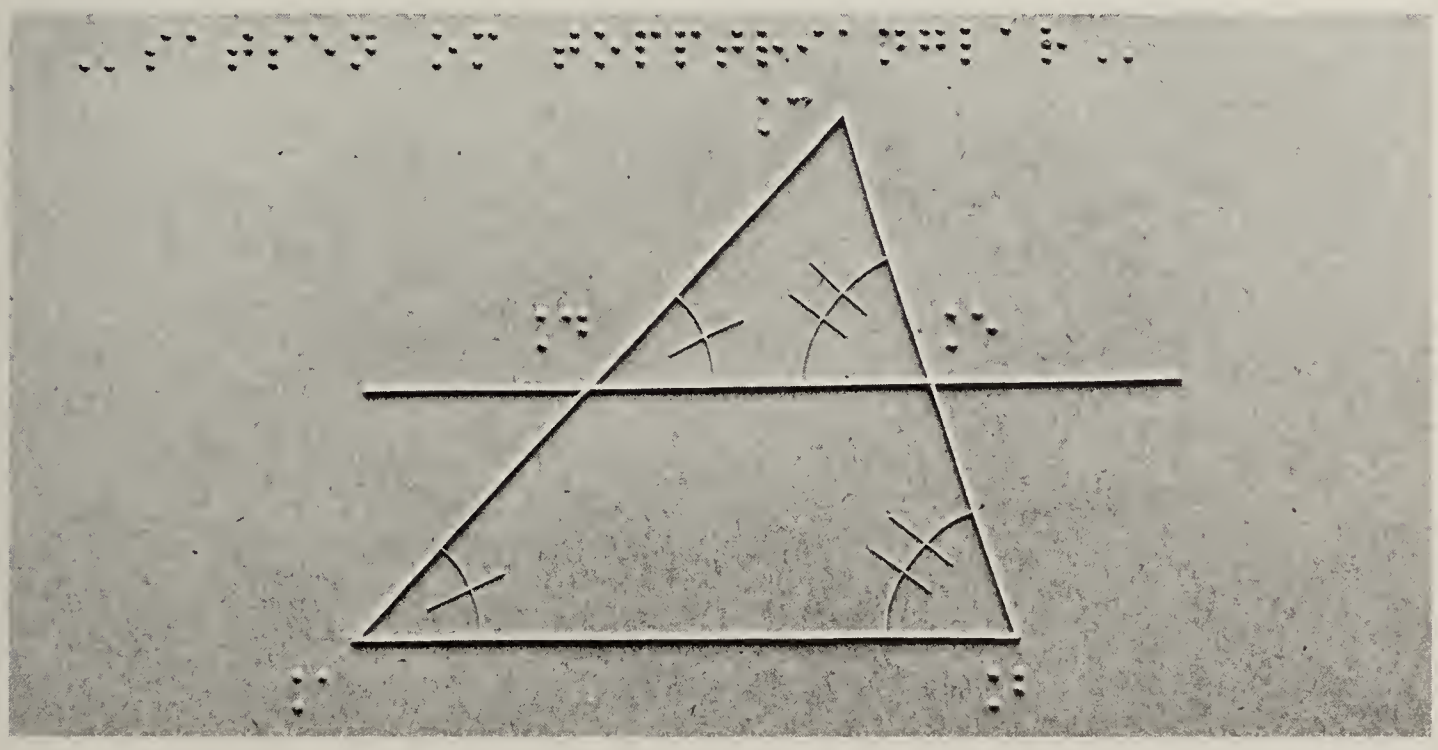




The angle shown on the left was made of coarse thread with an embossed angle symbol. The angle symbol should be embossed before the thread is glued to the page. In the display on the following page, the angles were embossed with a fine spur wheel.



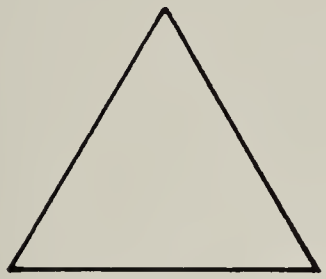
The following angle symbols indicate two pairs of angles that are equal—angles A and D and angles B and E. The triangle and dividing line were made of coarse thread, the angle symbols of very fine thread.



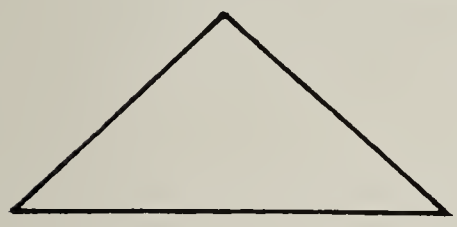
The display shown below makes use of various elevations and textures. The dark arrows were made of sandpaper, the large white arrows of heavy cardboard, and the angle of heavy carpet thread (it is the same elevation as the white arrows). All the other lines were made of semicoarse thread. The lines at a right angle to the arrowheads were made of knotted, preglued thread. The braille labels were cut from braille paper (they should have been made directly on the background to eliminate the text boxes).

Should this display have been made in the first place? It is doubtful, since it would cause utter confusion for blind readers. The presentation is definitely a *visual* interpretation. A possible solution would be to make a step-by-step series of illustrations, use a key, and finely emboss the helping lines (which, in the display, are part of the figure itself).

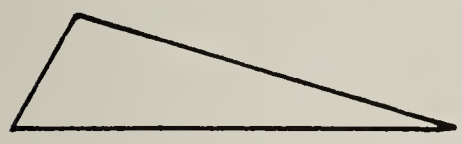
Types of Triangles



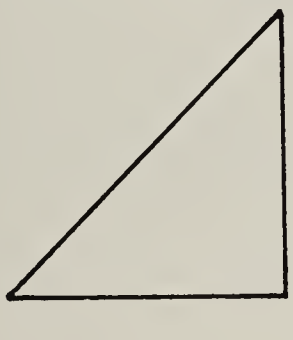
Equilateral—all sides equal.



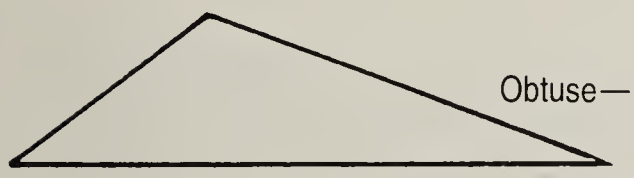
Isosceles—two sides equal and two angles equal.



Scalene—all sides unequal length.



Right angle—one angle a right angle.

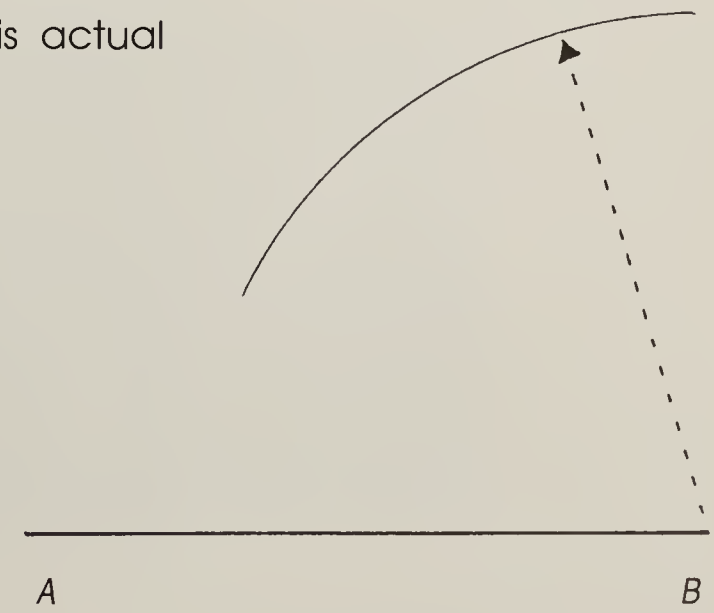


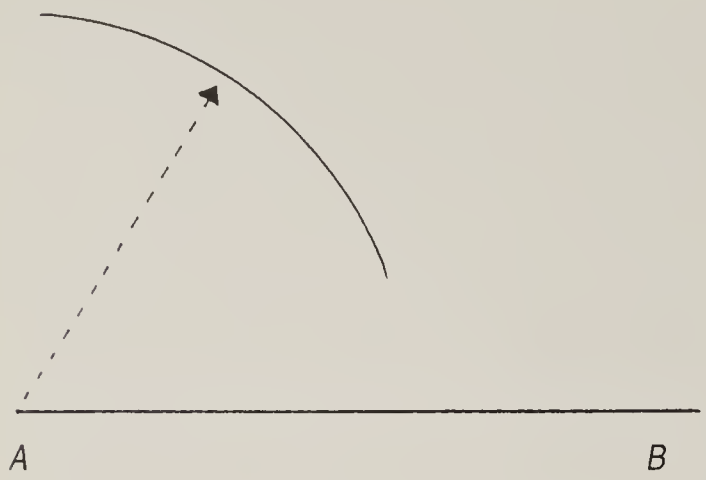
Obtuse—one angle between 90° and 180.°

How to Construct Triangles

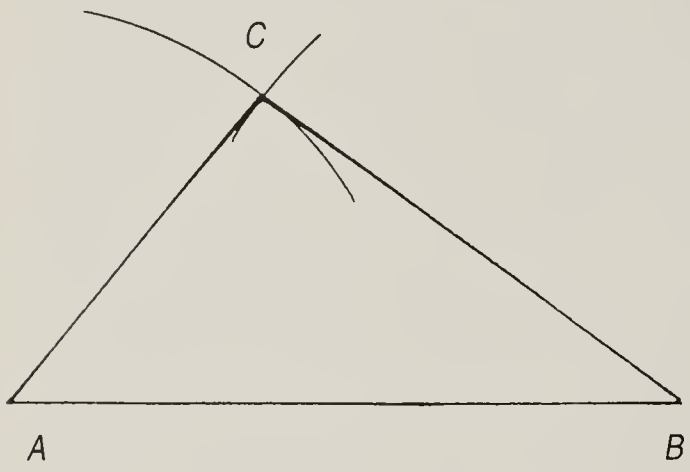
To construct triangles, you will need a ruler and a compass. To construct a triangle with sides of specific lengths (in this example 3.5 in. [9 cm], 2.7 in. [7 cm], and 2.1 in. [5 cm] were used; the illustrations shown are reduced and are not this actual size), do the following:

1. Draw the baseline, AB = 3.5 in. (9 cm),
2. Place compass point on B,
3. Measure 2.7 in. (7 cm) from the compass point, and
4. Draw a curved line at this point (this line will have a length of 2.7 in. [7 cm]).



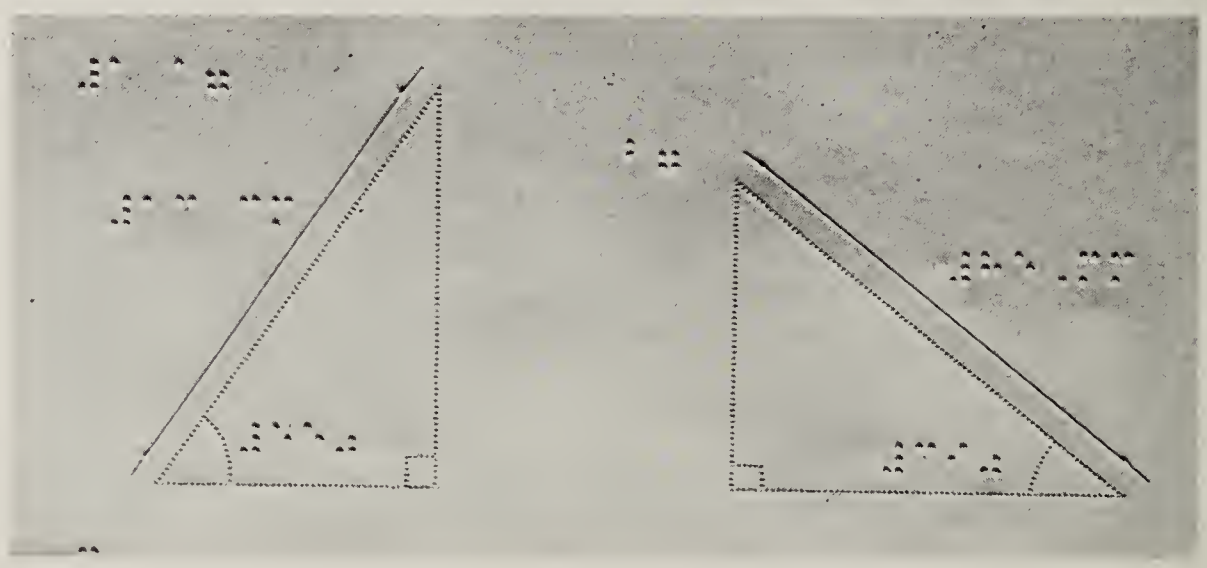


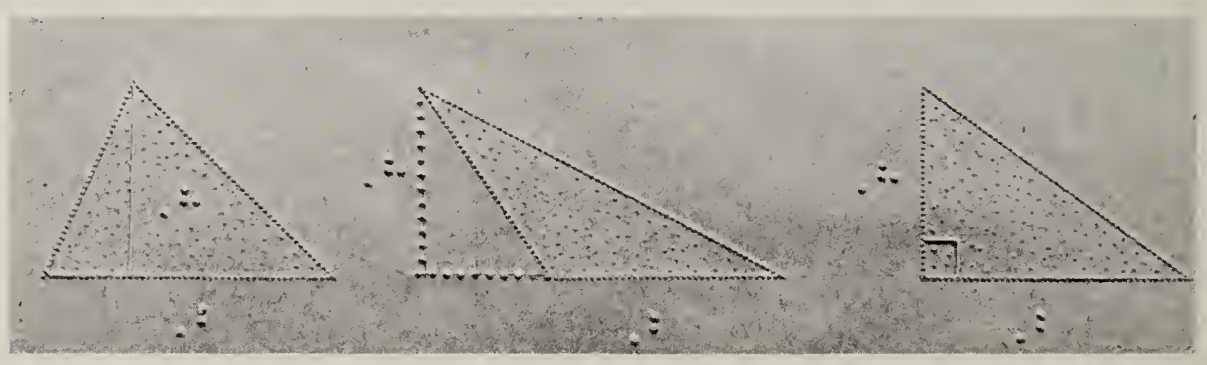
5. Next, place the compass point on A. Measure 2.1 in. (5 cm) from the compass point. Draw a curved line at this point (the length of this line is 2.1 in. [5 cm]).

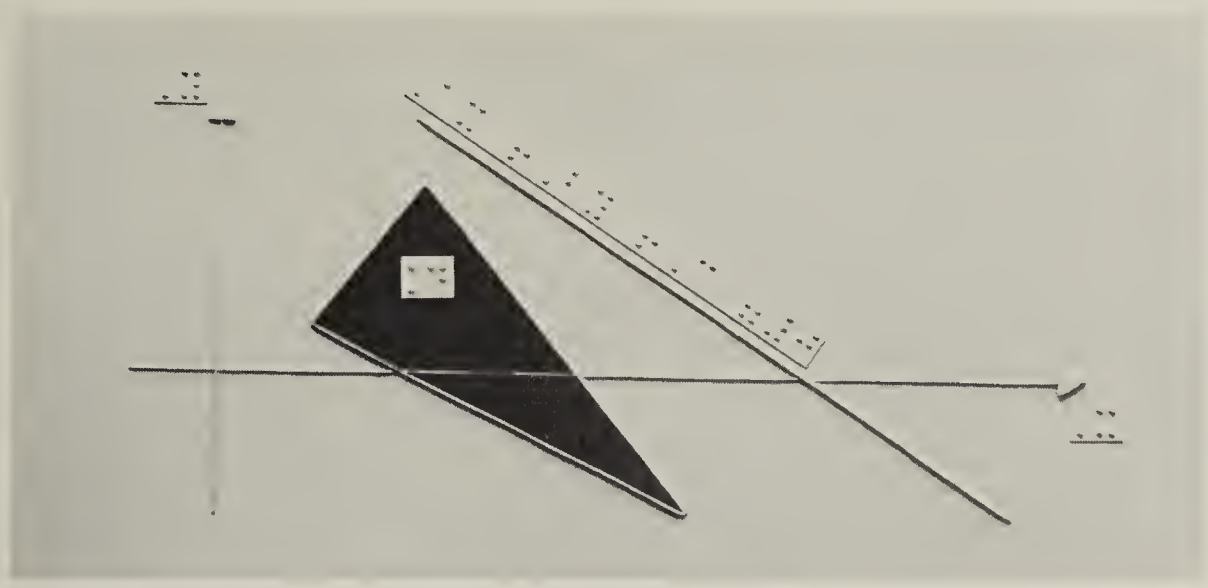


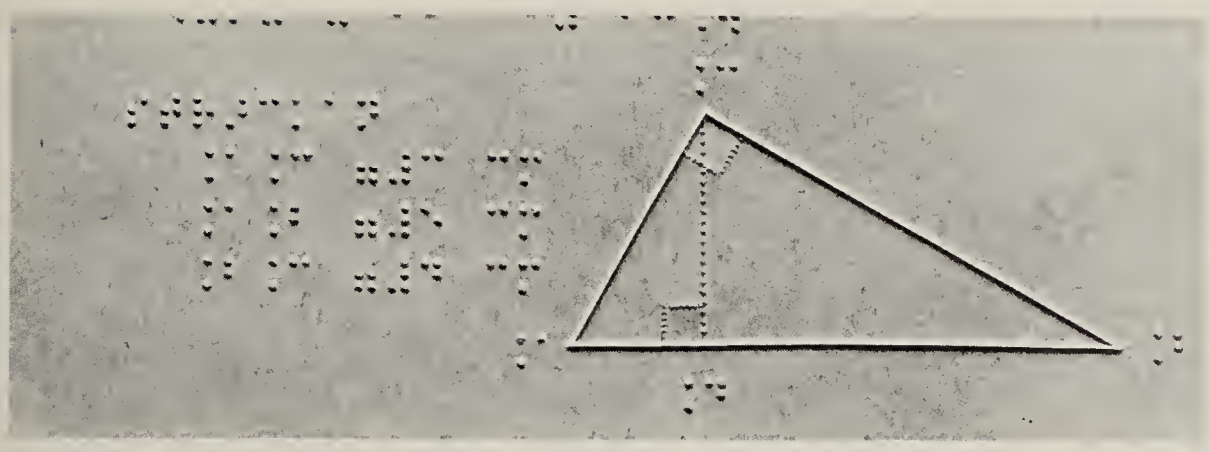
6. The point where the two curved lines cross each other is C. Complete the triangle by drawing lines AC and BC.

The following are examples of triangles made with spur wheels, thread, and sandpaper.



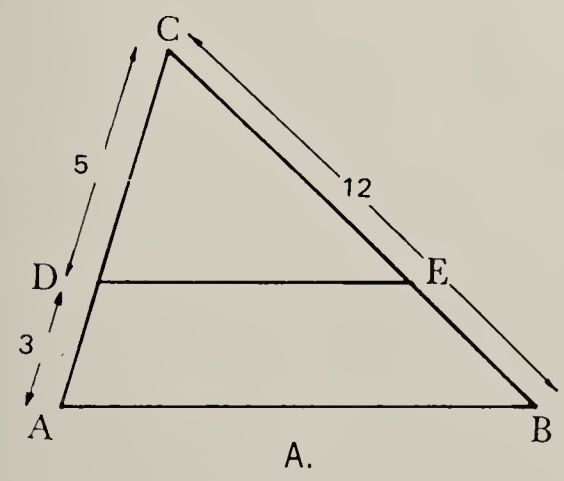




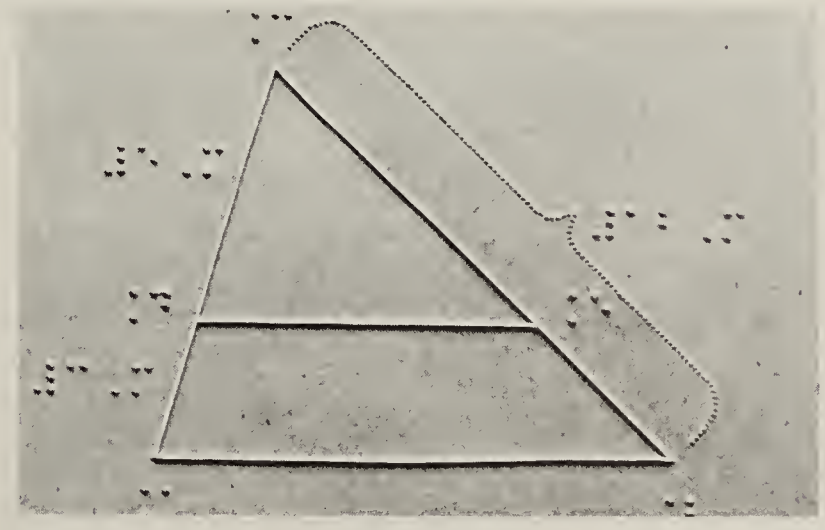


Brackets

A bracket is a symbol often used to join several parts of a figure. These parts usually fall under one heading or relate to one numerical amount. Brackets are an accepted and much used symbol in the visual world, but is their use in their traditional form ({) obvious to blind readers? It seems that the producer of the following relief display (see B) thought so. Note that the original printed version (see A) used a straight line.



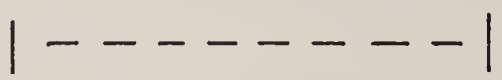
A.



B.

In a braille text, a bracket is transposed into a braille figure that consists of a formation of raised dots. In relief graphics, the bracket is most often indicated by a dashed or dotted line with a stopper at either end. For example:

Finely embossed line, dots made with a jumbo-dot correction tong.



Dashed embossed line, end stops made by pressing the end of a screwdriver into the reverse side of the paper.

Embossed line and stops, arrowhead dots made with a correction tong or slate and stylus.

Line of very fine thread, arrowhead stops made of paper or thin cardboard.

Embossed line.

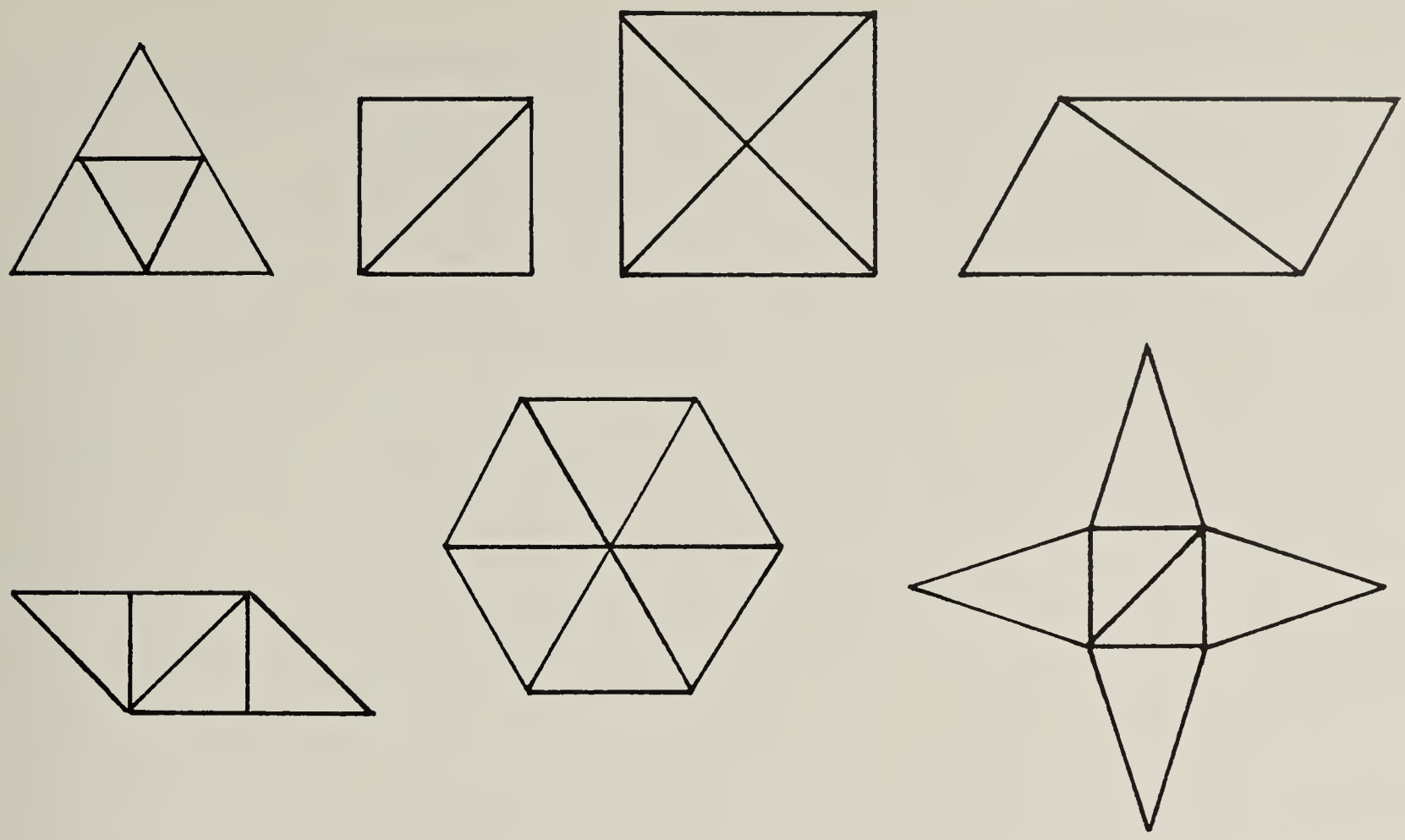
Line of fine thread with knotted ends.

These suggestions, excluding the last one, can also be used on microcapsule paper originals by drawing them with a pen.

Because a bracket is only a helping line, it should not be prominent. It should be light in character and of a texture that is different from the figure that it modifies.

Triangle Package

A useful teaching aid is a triangle package, whose contents are a set of cardboard triangles. The number of pieces is unlimited. Each triangle belongs to a particular group: acute, equilateral, obtuse, and so on. These triangles are used as a tool in the recognition of types of triangles and measurement of angles. They also show the position triangles play in forming other geometric figures.



Examples of cardboard triangles used in a package.

The cardboard triangles may slide around when the student is working with several of them at the same time. Magnetic tape, a cardburr band, or non-drying caulking material (such as Blu-Tack) fastened on the back of the triangles will help eliminate this problem and should be mentioned in the directions that you provide with the package. Antislip cloth will also inhibit the triangles from sliding if they are placed on the cloth. The cloth is usually sold by the yard (meter) and is available from marine supply stores.

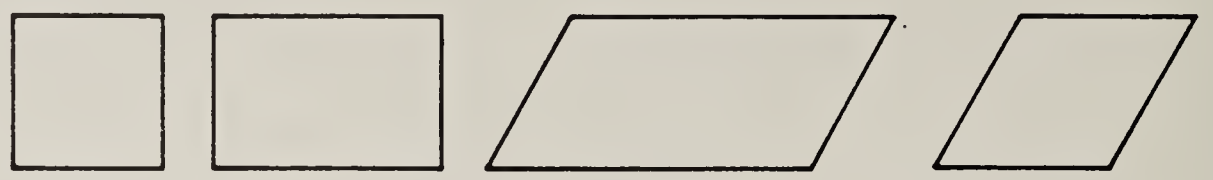
GEOMETRY

Geometry is the branch of mathematics that deals with the measurement, properties, and relationships of points, lines, angles, surfaces, and solids. Plane geometry relates to the properties of two-dimensional figures. Solid geometry deals with the properties of figures in space (three-dimensional figures).

Planar Geometric Figures

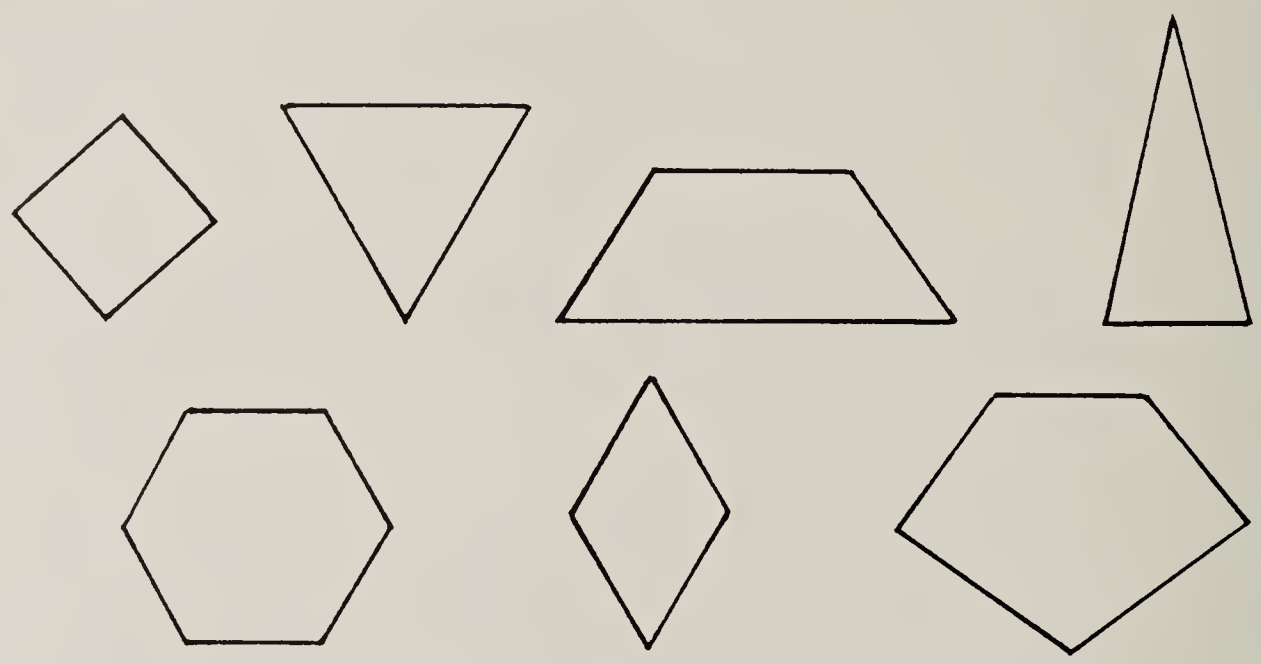
Triangles, quadrangles, circles, and polygons are found in plane geometry. (Circles and triangles have already been discussed and are therefore not included in the discussion here.)

- Quadrangles consist of four points connected by four lines. Parallelograms are quadrangles with oblique angles (acute and obtuse), whose two pairs of opposite sides are parallel and equal in length. Rhombuses are equilateral parallelograms.

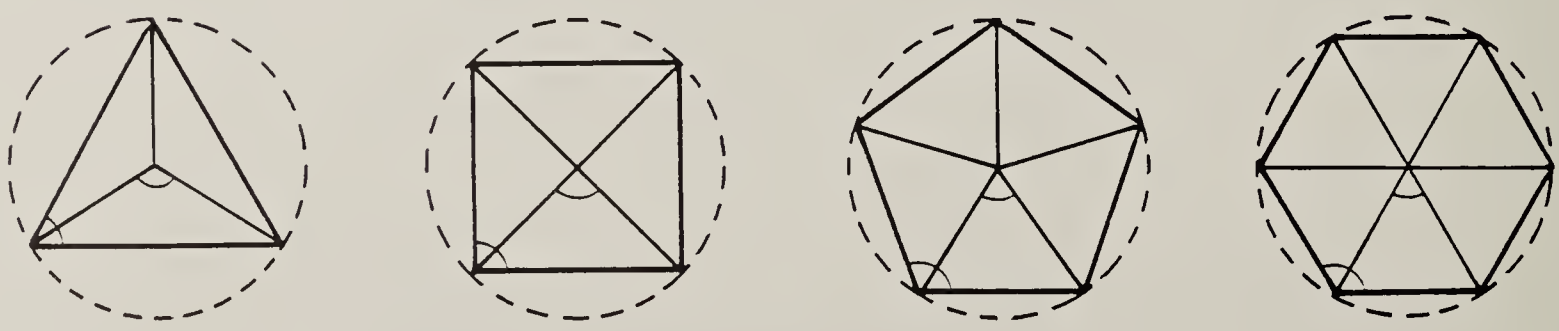


Square Rectangle Parallelogram Rhombus

- Polygons are closed planar figures bounded by at least three intersecting line segments.



A polygon is symmetrical when all its sides and all its angles are equal. This type of figure is easily made by drawing a circle first and then using the center point of the circle as the meeting point of the vertex of the triangles that form the polygon.



Solid Geometric Figures

The presentation of solid geometric figures for blind people has its problems, not the least of which is the explanation of the

relationship of the various planes of a three-dimensional figure on a two-dimensional plane. The use of three-dimensional geometric shapes as teaching aids is indispensable. However, these forms are not equipped with the numerical information on the length, width, and sizes of angles; bisecting planes; and division of areas that is necessary for students to solve geometric problems. A relief display is still desirable.

Considerations for Teaching

Each of the figures on the following pages is presented in two forms:

1. A flat layout showing top, bottom, and side views of the planes of the geometric figure. These areas can be numbered in size according to the textbook problem. The relief display that is to be measured by the reader for overall size, length of sides, or width of angles should be the same size as the one printed in the original textbook.
2. A model of a braille paper, thin cardboard, or microcapsule paper figure that is made to be cut out and folded to form a three-dimensional figure. By working with such figures, the blind student becomes acquainted with the three-dimensional object in a flat two-dimensional form.

A package of foldable geometric forms can be made as a separate unit for beginning geometry students. After the students have inspected the relief display of a figure, the teacher can cut it out, fold it along its dotted lines, and fasten it together with tape, a paper clip, or reusable adhesive to form a three-dimensional figure.

In the package, instructions should explain that the parts of figures made of cardboard should be cut out individually. The students should be shown these parts one by one to build up their knowledge of the different planes that make up a geometric figure. The parts are then taped together on their reverse sides with a pliable tape that can be folded many times. These figures are then fastened together as mentioned above.

Instructions should also explain that all figures can be labeled with numbers or letters by embossing them with a slate and stylus or by fastening prebrailled labels to the various

planes. Labels facilitate identification of areas or the presentation of numerical values for particular problems.

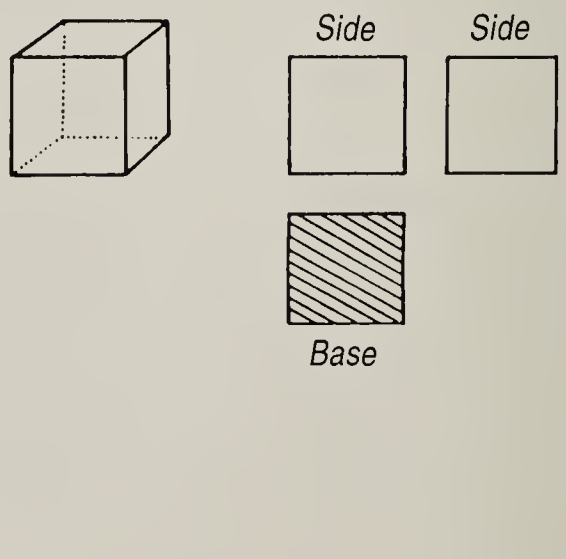
Three of the drawings in this section, made on a raised-line drawing board with a ballpoint pen, were drawn by a young, congenitally blind man in a research program in Finland (Ihanainen, 1987). He was thoroughly acquainted with the three-dimensional objects that he drew, but he was not familiar with the foldout type of geometric figures pictured here. His drawings are presented to show that blind persons can indeed visualize geometric forms.

Each geometric figure shown here in a flat layout illustrating side, end/side, and base views is followed by a cut-and-fold drawing. The inkprint figure to the left in each section presents the geometric figure as it usually appears in textbooks. Visually impaired students often ask to have this figure included in their relief information. They want to feel the same figure that their classmates are seeing and discussing. When making a relief display, be careful that this inkprint figure does not become a physical part of the figure presented. Distance from the other parts of the display and a few words above or beside this figure will make its purpose clear to your readers.

Specific Figures

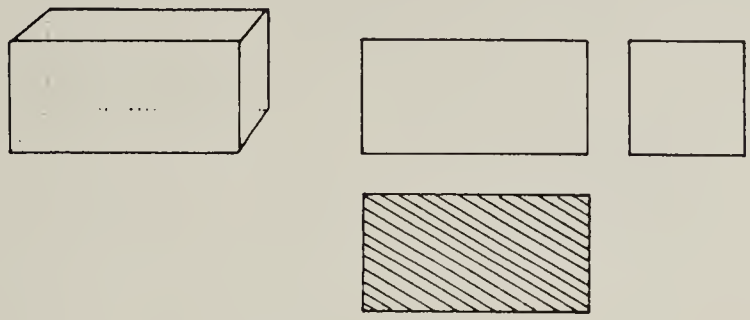
Prisms are solids whose base or ends are any similar, equal, and parallel plane figures and whose lateral faces are parallelograms.

Cubes are quadric prisms with six equal sides.



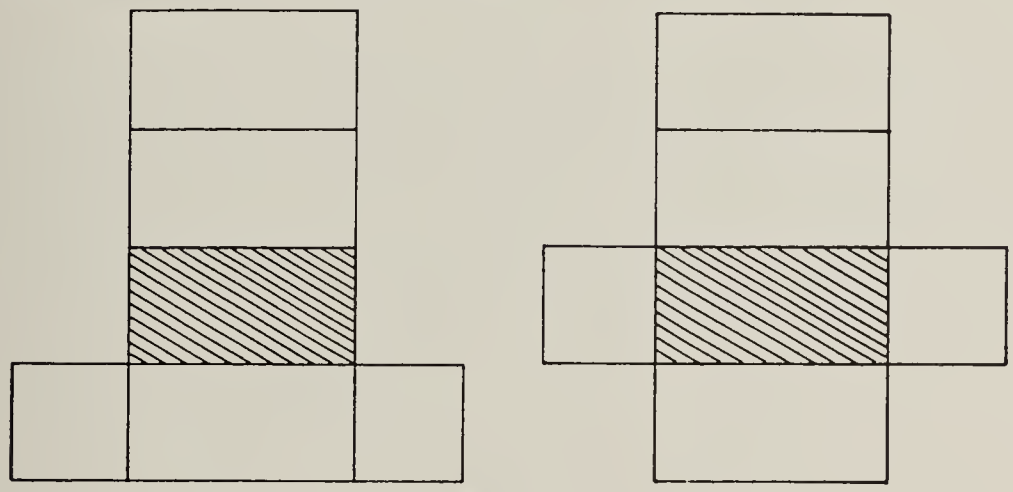
The actual size of the square used, whose sides are 1 3/4 in. (4.4 cm) in length, is easy for blind students to use.

This rectangular solid is a rectangular parallelepiped, a six-faced polyhedron all of whose faces are parallelograms lying in pairs of parallel planes:



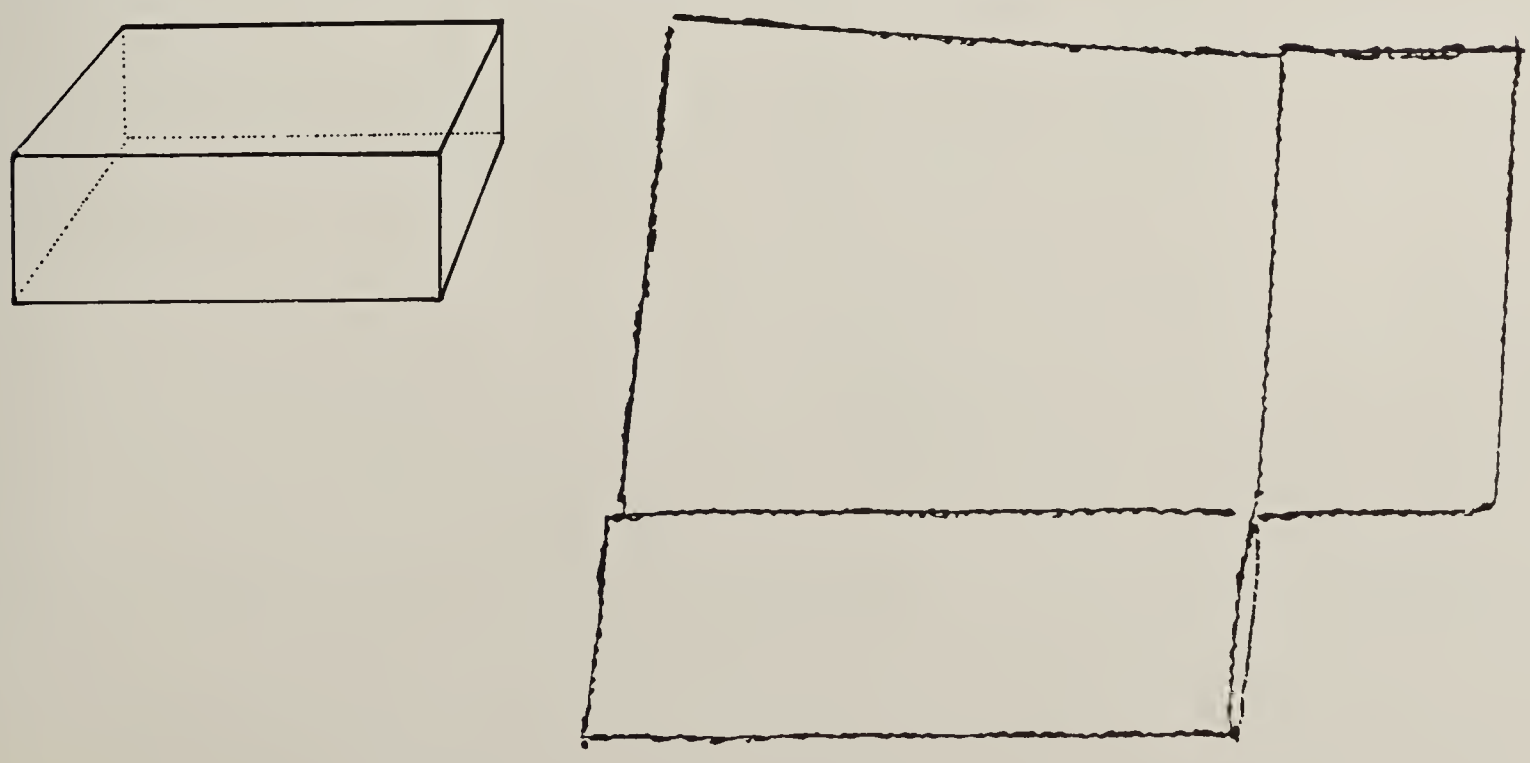
1. This form is easier for the student to put together.
2. This one is easier for the student to understand when it is in a two-dimensional form.

The production choice is up to you. Test them on blind readers before you decide.

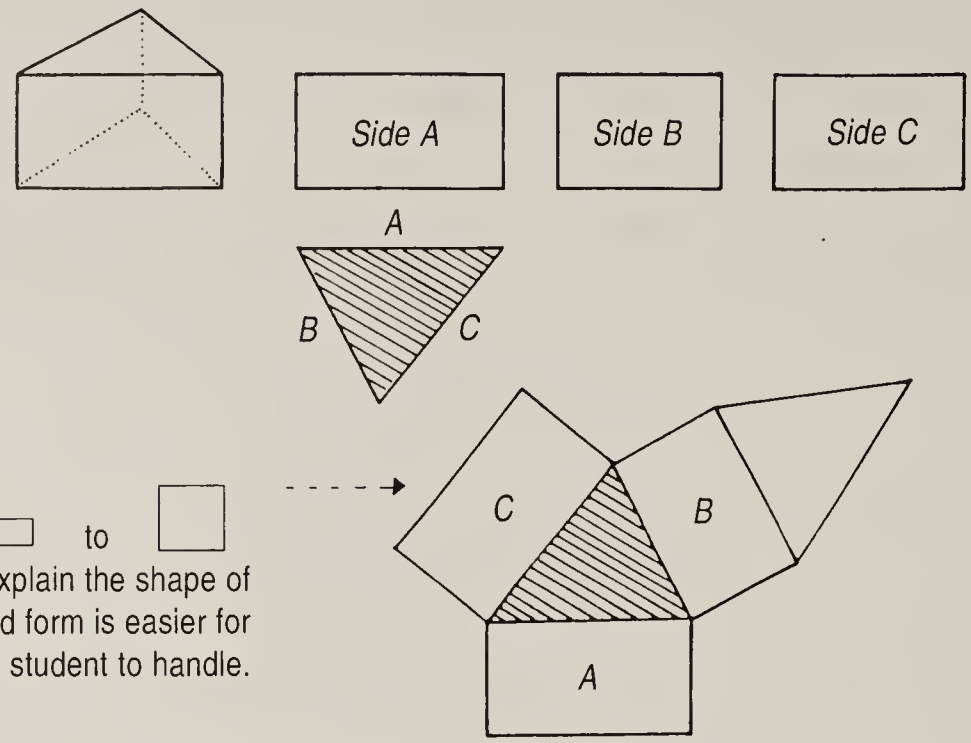


1. 2.

The drawing that follows on the right shows the young blind man's impression of a rectangular solid. The drawing has been reduced to approximately 65 percent of its actual size.

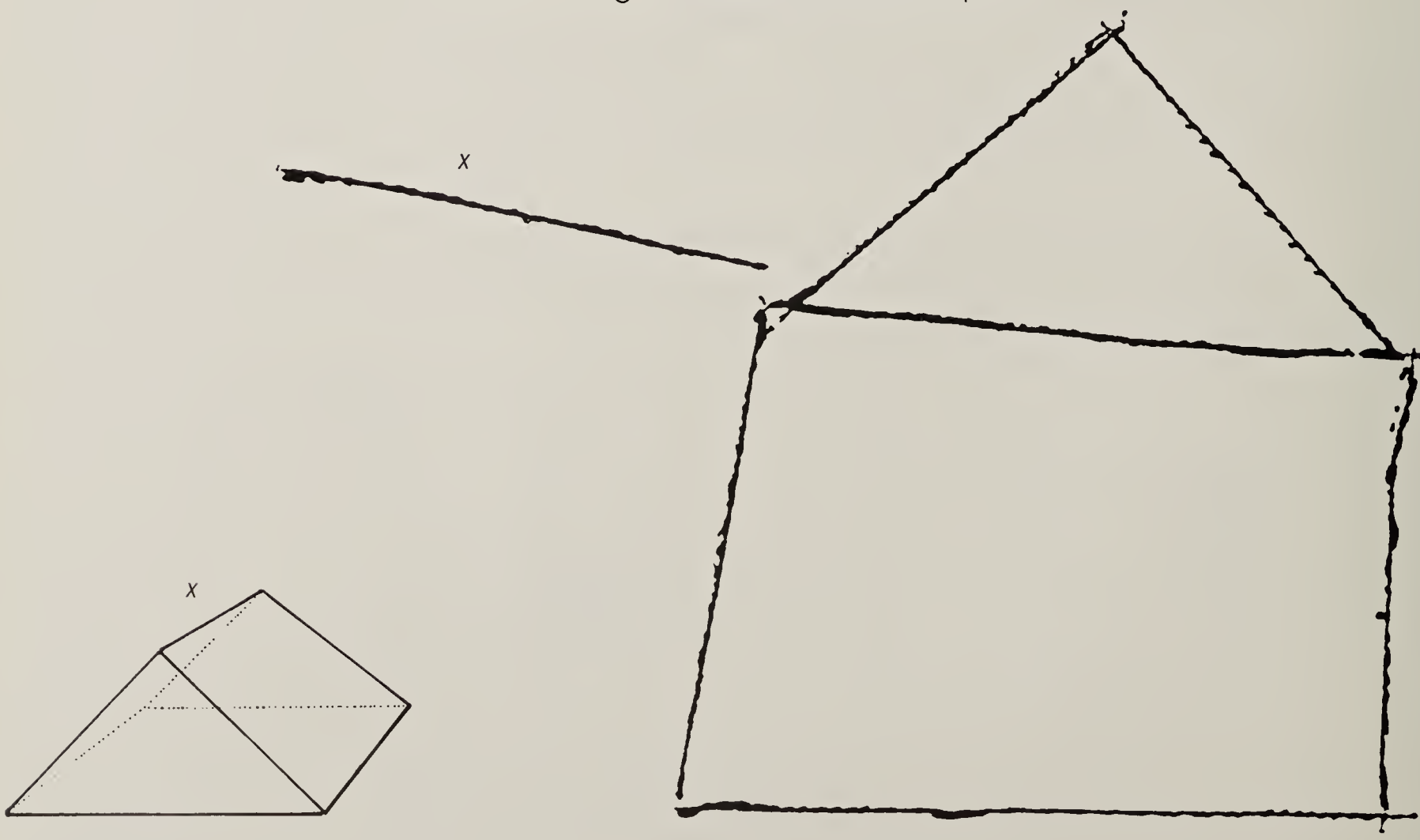


Following is a three-sided prism:

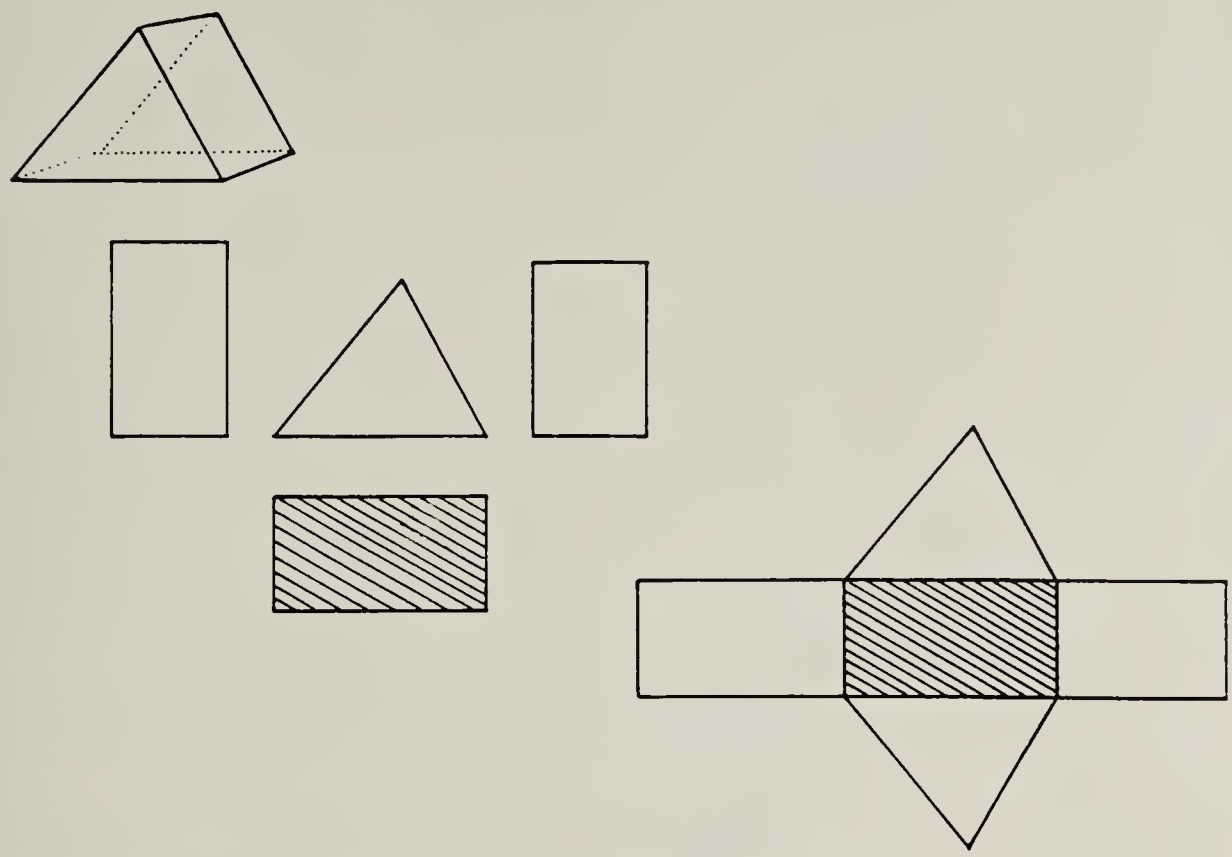


Lengthen the sides from ▭ to ▯ when making a cut-out display to explain the shape of a three-sided prism. This elongated form is easier for the student to handle.

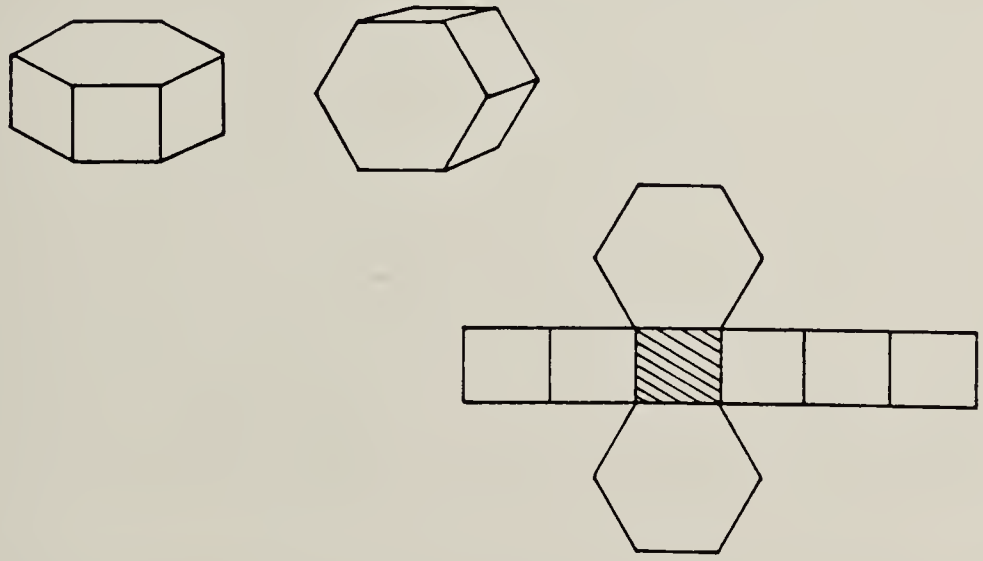
Here is a drawing of a three-sided prism. The figure on the right shows the young blind man's impression of the figure. Two of the lines that are meant to correspond to each other have been indicated by *x*s to show how the young man conceptualized the figure of the three-sided prism.



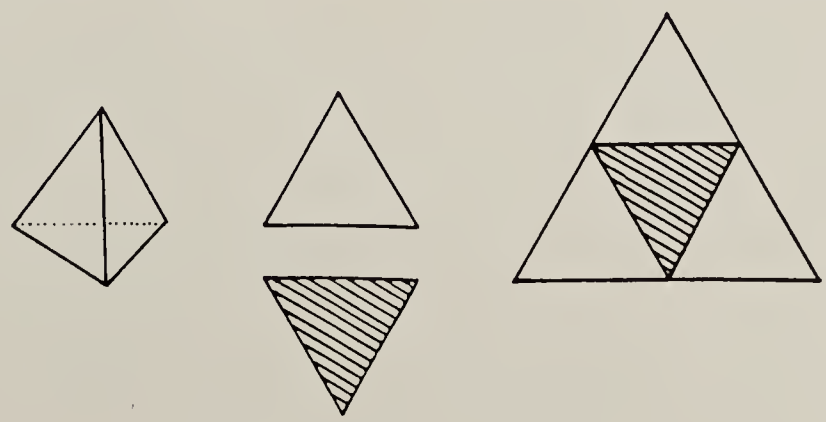
Here is the same three-sided prism in another position.

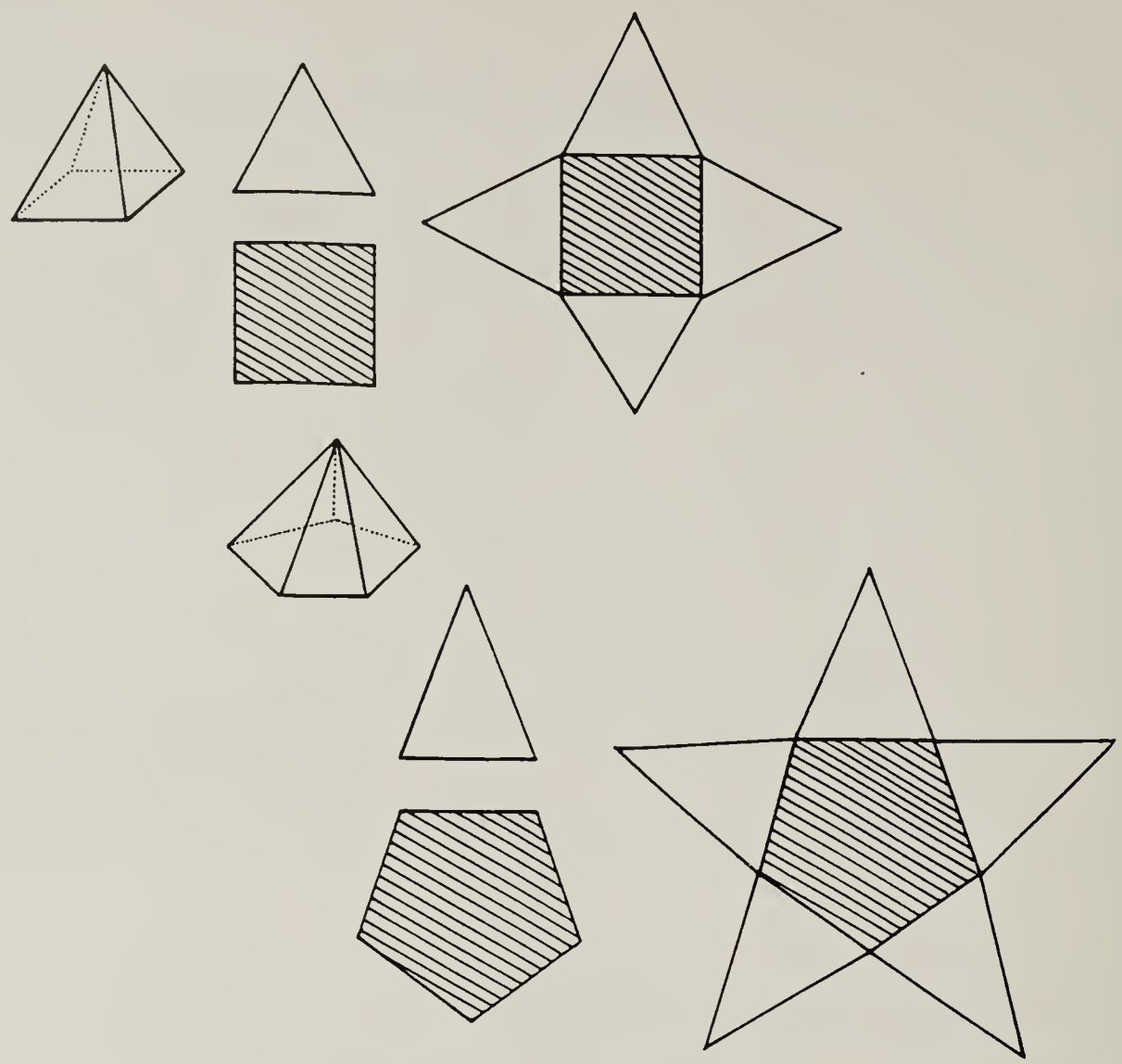


Here is a hexagonal (six-sided) prism.



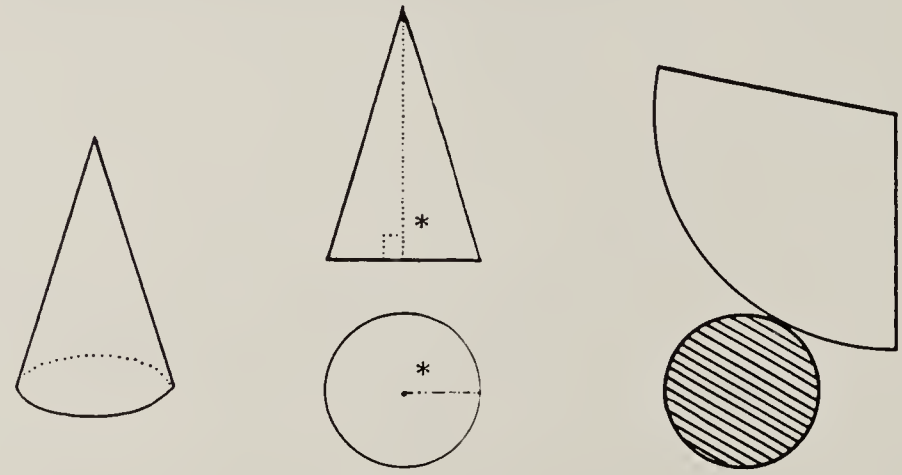
Pyramids are solid forms with a polygonal base and triangular sides that meet in a common vertex. Here are some examples:



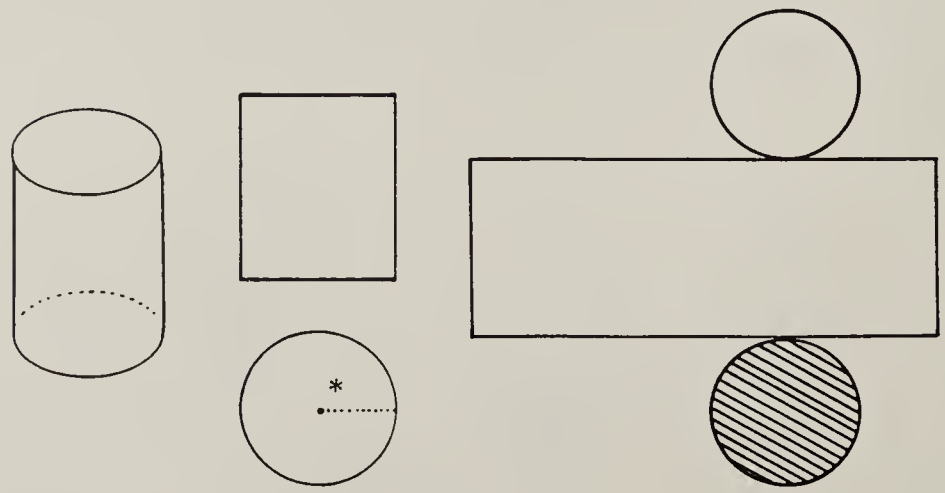


Cones are constructed as follows:

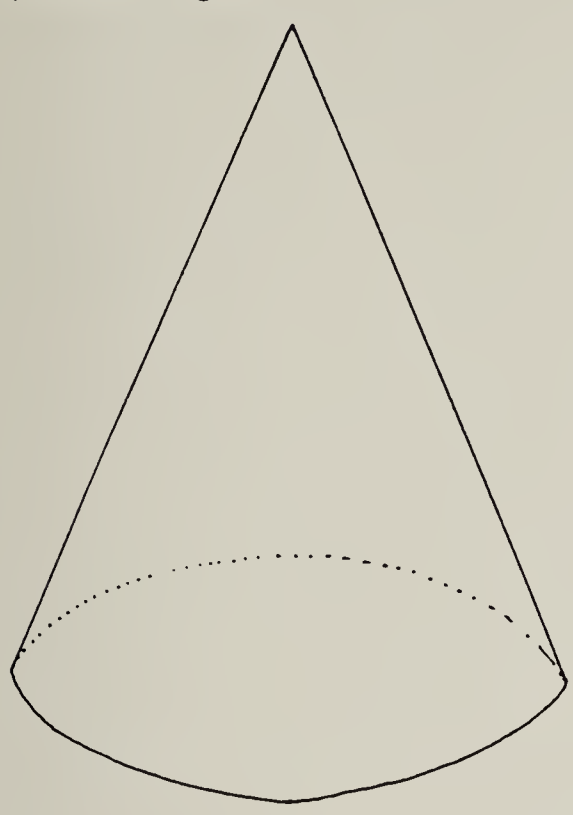
* *Note:* Lines indicating the height of the triangle and the radius of the circle must always be included.

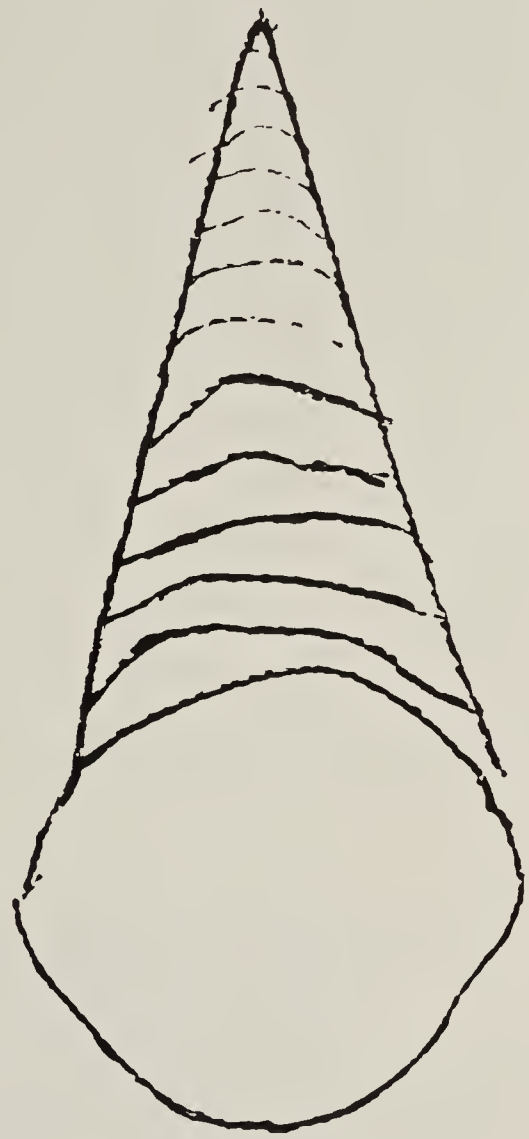


The following are the components to construct a cylinder:

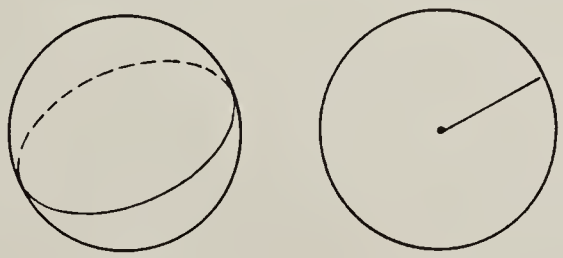


These illustrations show the actual size of a cone used in the research program, reduced by 50 percent, and the drawing that was produced by the blind student (reduced by the same percentage).

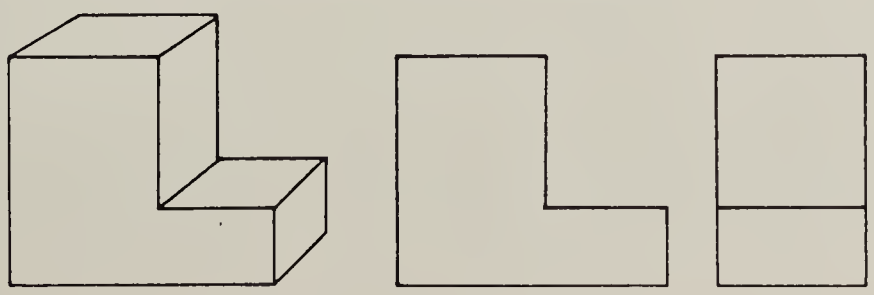




The sphere is included here only to indicate its place among geometric figures. Its form is so well known that it seems unnecessary to describe it graphically. Two points must be shown in a graphic layout—the center point and the radius.

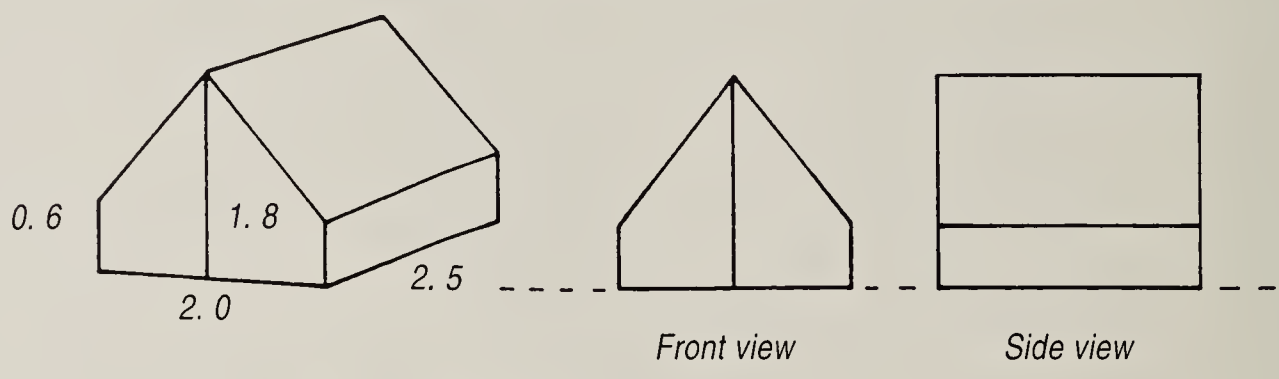


The flat layout technique can also be applied to figures that are a combination of geometric forms.

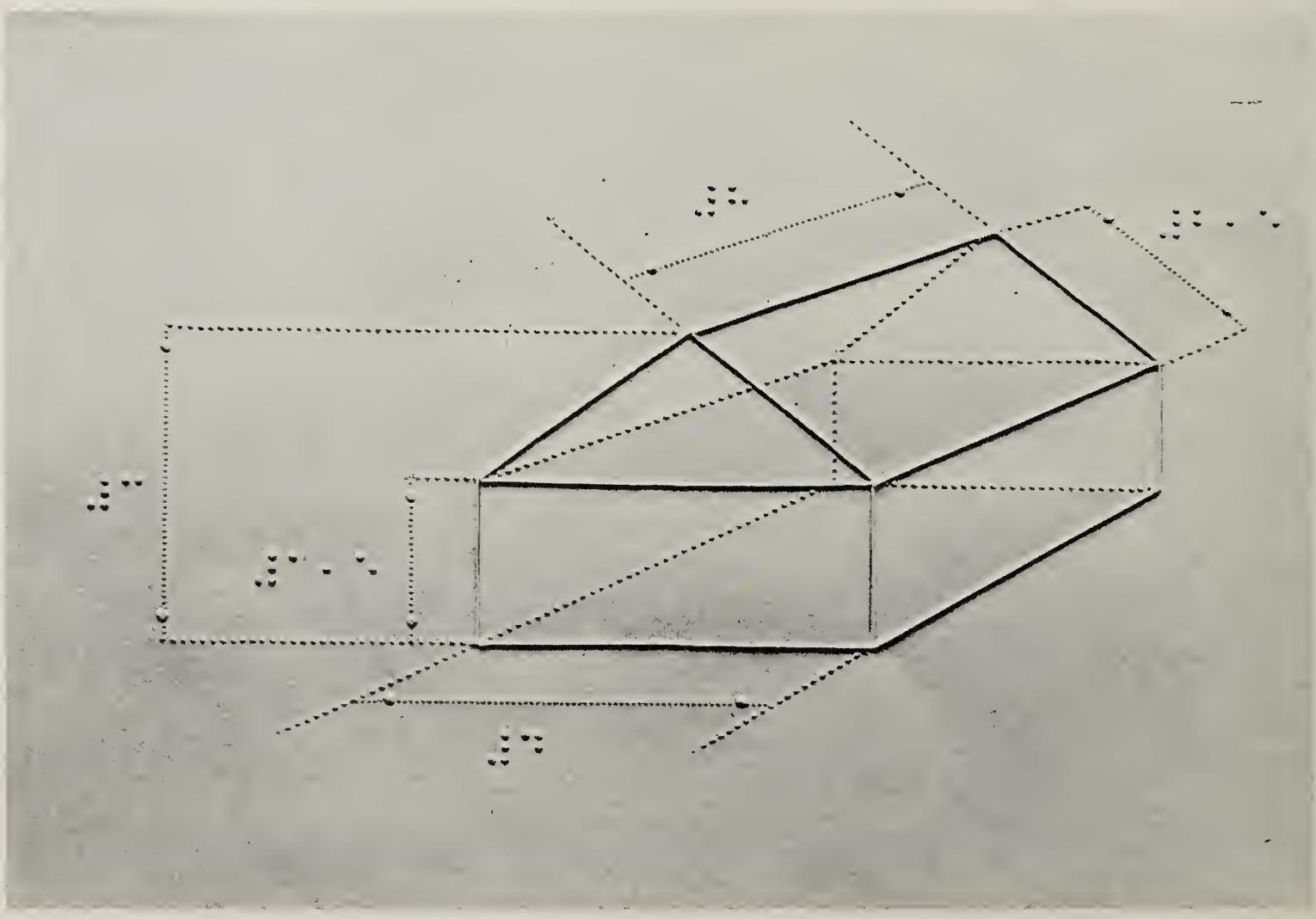


The base areas shown on the previous pages are a means of presenting all the surfaces of geometric figures to beginning students. Base areas in the illustrations of problems are superfluous and should be left out when students understand the composition of the common geometric figures. However, for complicated problems with bisecting areas or lines involved, it may be useful to include a base plane. If an illustration is necessary to add to or clarify the information in a textbook, give your students a simple front and side view of the perspective illustration in the textbook.

Here are two presentations of the same type of problem, which concerns the volume of a tent. The first problem:



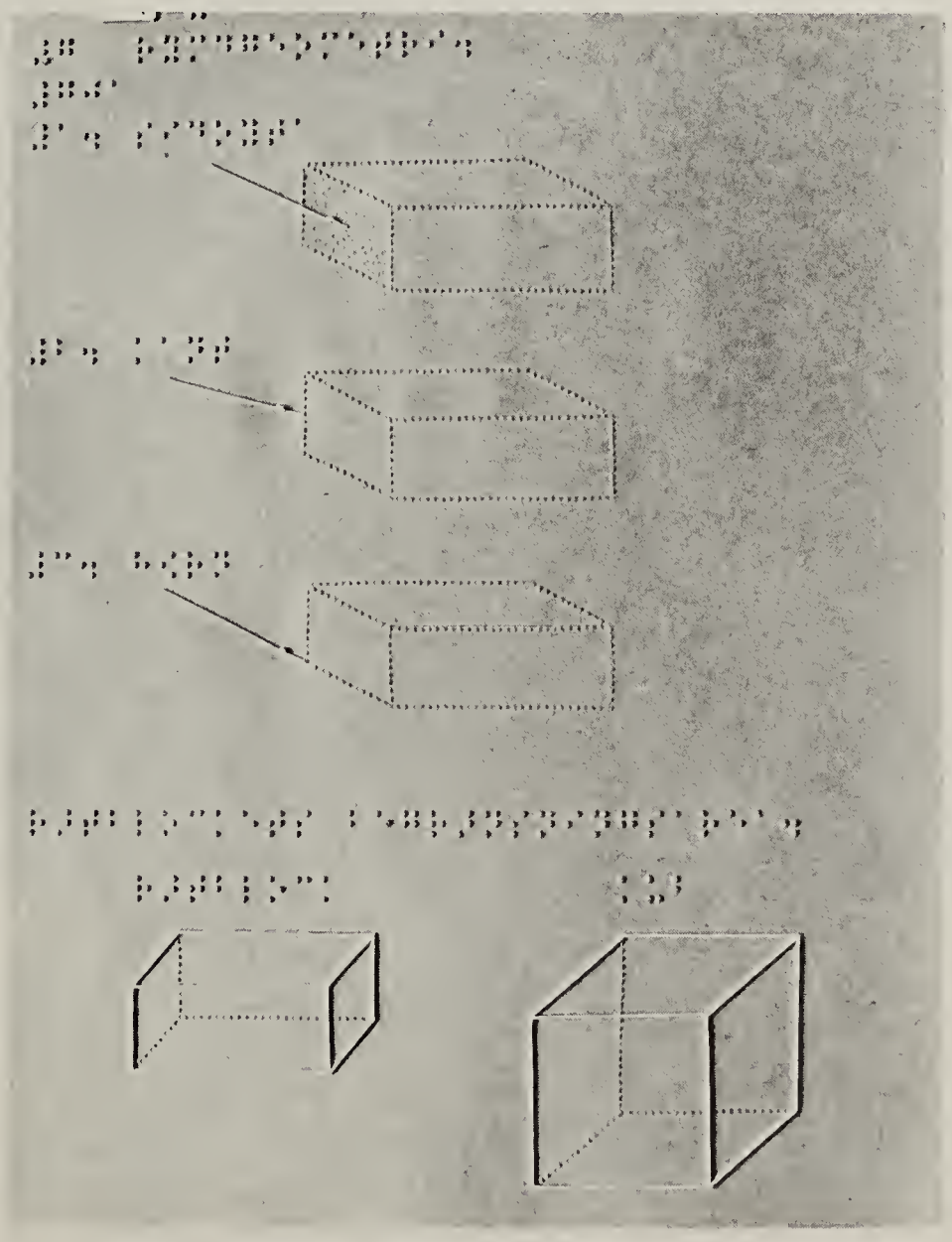
The next problem asks the reader for the volume of a house:



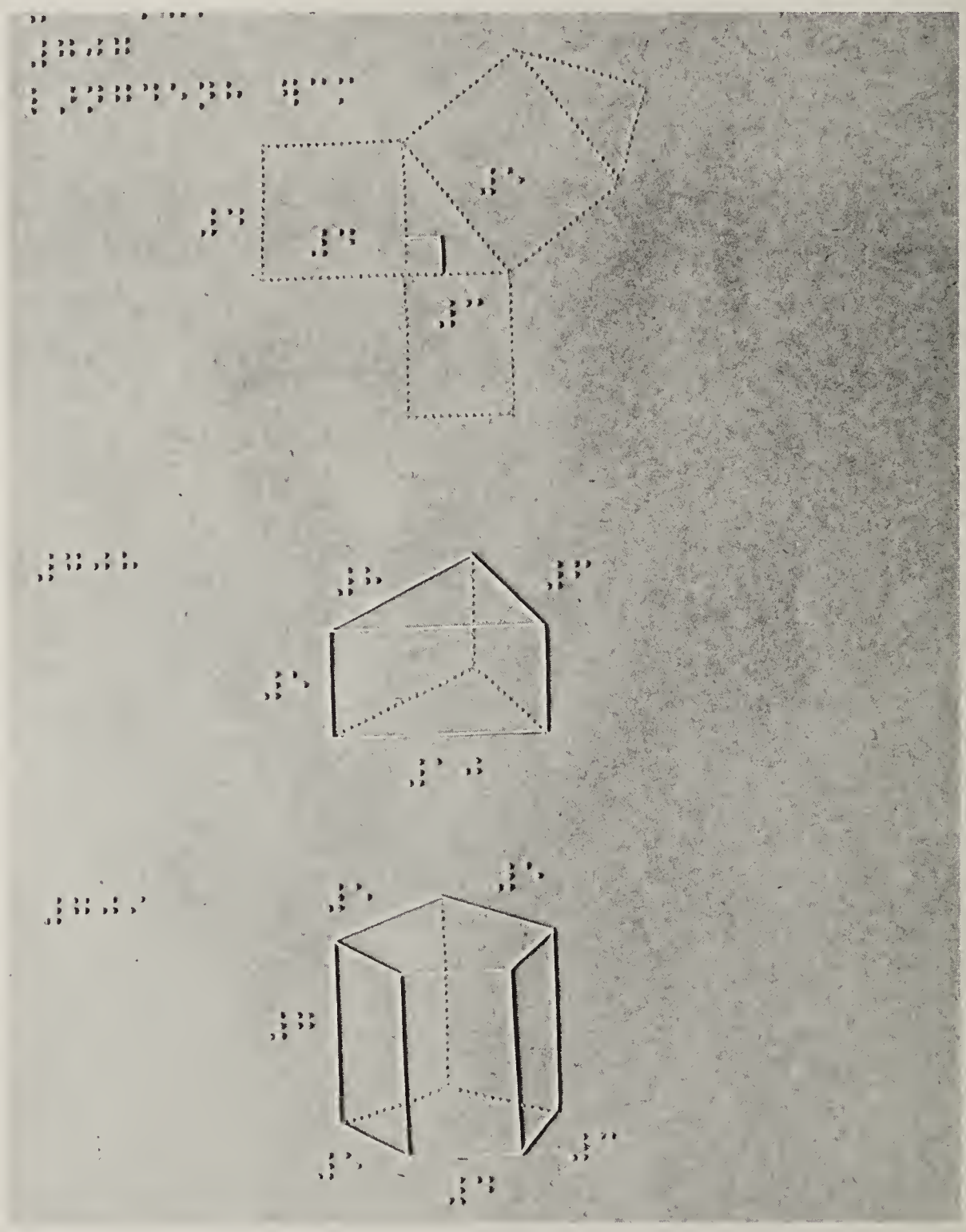
Both problems, although similar, are presented in different ways. The perspective projection shown in the second display is difficult for blind students to understand. Although the string outline of the house gives it some dominance, the array of embossed lines is confusing. A two- or three-plane house display would lead to quicker comprehension of this mathematical problem. The ability of the student to understand a graphic geometric display is the deciding factor when choosing the type of layout you should use.

Following are several illustrations of production techniques on buildup masters.

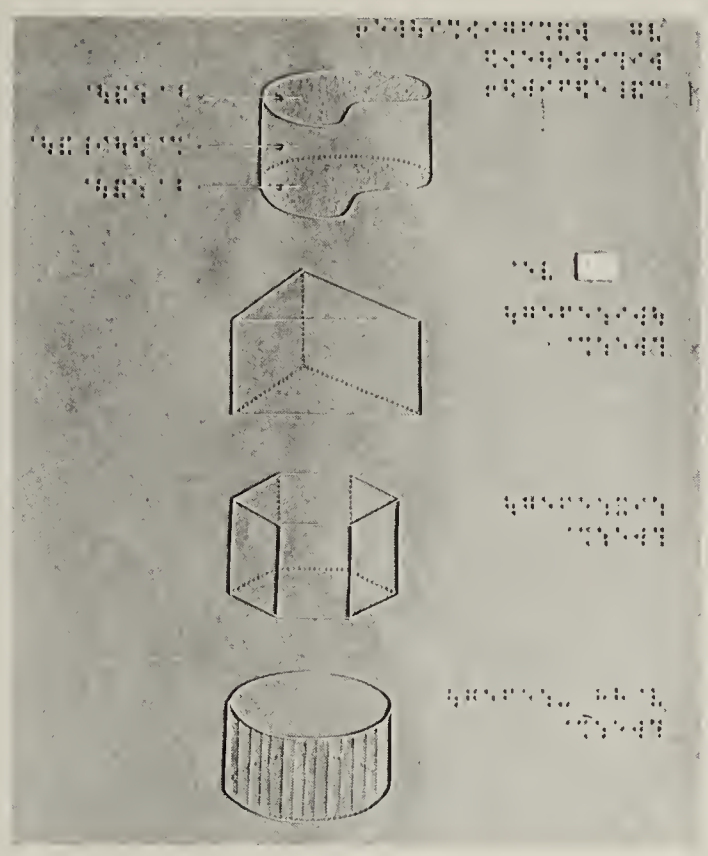
The embossed figures in the display shown below illustrate the meaning of the words "side," "edge," and "corner." The side is finely pricked with a pin on the reverse side of the paper. The arrows are made of thin thread knotted at the end. The figures of the cube and the rectangular solid are presented in coarse carpet thread; their hidden surfaces are outlined with a fine spur wheel.



In the next example, the producer chose the foldout technique to explain the composition of a prism. The figure was made with a fine spur wheel, and the symbol for a right-angle triangle was made of fine thread. The prism was made of coarse thread and finely embossed lines. The braille numbers correspond to the same areas shown on the prism in perspective.

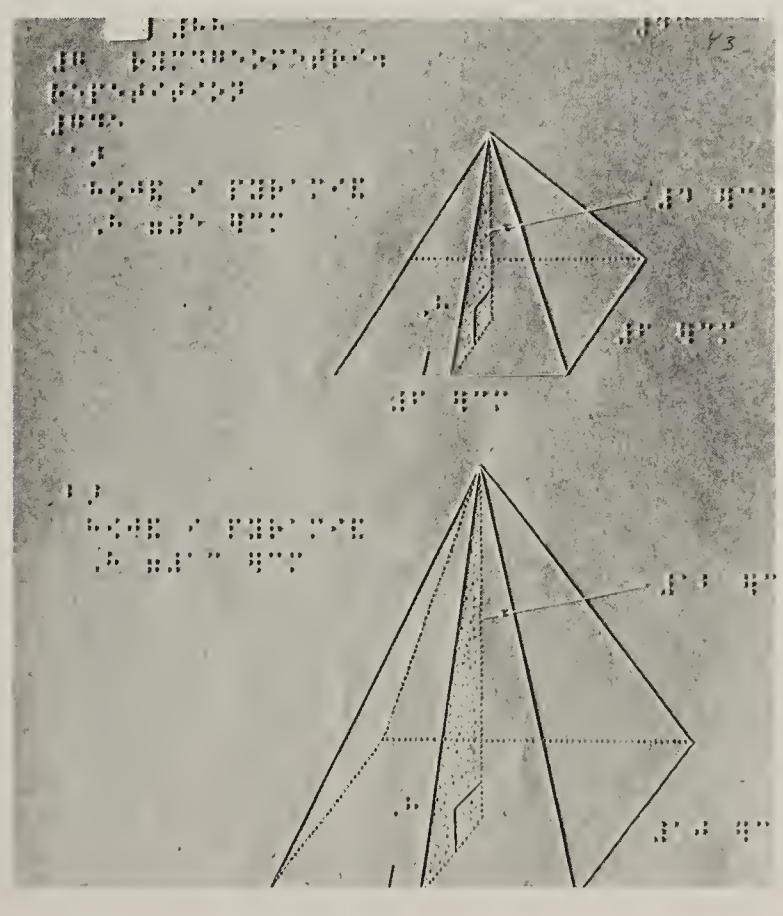


In the following display, a pricked area shows the top and base of the figure, as seen in the first cylinder. The mantle on the second cylinder is embossed with a spur wheel to give it a circular feeling—the same technique that the young blind man used in drawing the cone shown earlier in this section.

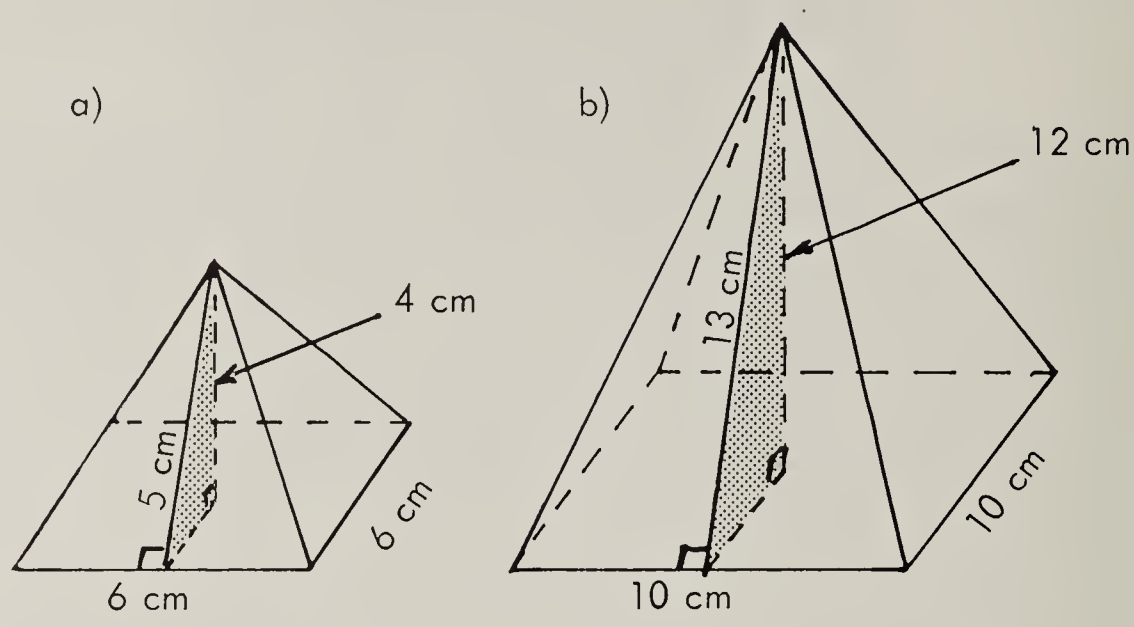


The preceding three examples could have been made on microcapsule paper with good results. This method of production is especially desirable for students with low vision who need both a relief display and a black-and-white illustration.

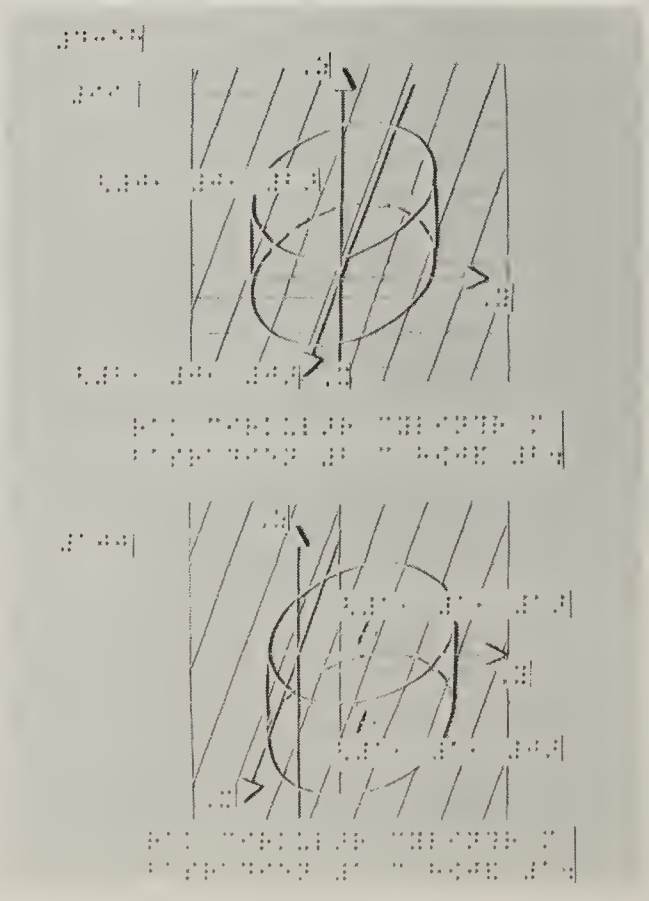
An explanatory section relating to the four-sided pyramid below shows that a right-angle triangle is formed by drawing a line from the pyramid's apex to the center of its base. A pricked area forms this triangle. If the pin-pricked area had been repeated beside each pyramid, the arrows would not



have been needed. The producer of this display followed the textbook illustration, shown below, exactly. The arrows that were used in the illustration and repeated in the display tend to become part of the pyramids' forms in the display and thus confuse the reader.



This last display is one that should never have been made. Labels, arrows, and grid lines make it impossible to get any idea of the geometric figures portrayed. This is a frightful example of a relief display directly transposed from a textbook illustration and should be a warning to all: Think with your fingers before making your layout for a relief display.



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Levi, J.M., & Amick, N.S. (1982). Tangible graphics: Producers' views. In W. Schiff & E. Foulke (Eds.), *Tactual perception: A sourcebook* (pp. 417-429). New York: Cambridge University Press.

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Tactual Maps:
Discriminability
Textures and Sh
VOYAGER

CHAPTER 9

Displays for Readers with Low Vision

The graphic requirements for persons with low vision are basically the same as those for blind readers. The main differences are the possible use of graphics made for sighted readers and possible addition of color in some instances. Occasionally, people with low vision will also use tactile graphic displays. However, the use of this type of aid will depend on the severity of the reader's visual impairment and his or her attitude toward relief materials.

The following are points to consider when making displays for readers with low vision. Pictures and maps should contain:

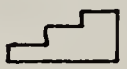
- few details and simple forms,
- a minimum distance between objects of 1/8 in. (3 mm),
- good contrast of shapes and colors,
- clear colors as opposed to muddy colors,
- dark lines outlining the objects in the display,
- bold black text and not colored text,
- simple perspective (if the use of perspective is necessary),
- a neutral and quiet background,
- figures and objects that do not cast a shadow (a shadow is difficult for the reader to separate from its object, because both forms are experienced as one object),
- material printed or painted on nonglossy paper or plastic.

The subtle variation of tones in photographs is difficult for the reader with low vision to interpret and understand unless

OPPOSITE PAGE: Various factors need to be considered when making tactile graphics for persons with low vision, such as the reader's possible use of optical devices.

there is a good contrast between areas. Be sure that photographs you use are not cluttered.

Mathematical diagrams on a grid-line system are difficult to read. Use a numerical or alphabetical system on the perpendicular sides of the diagram (see "Index Grids," Chapter 6). The same comment applies to mobility and general reference maps.

Pictures of known objects are easier for readers to understand than are pictures of unknown objects. This can also be said of symbols for objects. This stair symbol  is more readily understood than this one .

Map symbols should be large enough and far enough apart to be easily discerned. Their size depends on the limit of the reader's vision and the low vision aids that he or she uses.

TYPOGRAPHY IN LOW VISION DISPLAYS

Generally, good contrast and an enlarged type size make a text easier to read. Large-print information can be produced on computers, on some types of word processors, and on office copying machines that are able to increase or decrease the size of the copy. Be sure that the lettering is sharp. Never underline a word or sentence in the text. The line becomes part of the lettering and makes reading difficult. If emphasis is necessary, set the word or sentence with a bolder type face.

The following comments apply to the majority of people with limited vision. However, no two people see things in the same way. This complication makes it difficult to give definite answers about the various problems involved in making displays for low vision readers.

Type Styles

Type styles can be divided into two main groups: those with serifs (the fine cross-stroke terminations of letters, usually seen at the top and bottom of a line), such as Bodoni, Caslon, and Garamond, and those without serifs (called sans serif), such as Gothic, Futura, and Vogue. Sans serif is the style usually preferred by people with limited vision. It is simple, uncluttered, unpretentious, and easy to read. This type is also usually

preferred by readers who use the Optacon, a reading machine that through electronic impulses converts the printed word into a relief display.

a b c d e f g h i j k l m n
A B C D E F G H I J K L M N

Type with serifs.

a b c d e f g h i j k l m n
A B C D E F G H I J K L M N

Sans serif type.

There are other readers who say that letters with serifs are easier to read because the variation in heights and shapes between letters is more prominent than in sans serif type. This makes the letters more readily discernible. Here again, what the reader finds easily legible depends on a variety of factors, such as the seriousness of his or her impairment. If possible, test both types of letters on readers before selecting the type for your display.

Weight of a Type Face

Letters can be printed in several different weights. For example, the type face Futura is shown in four different weights here.

Futura Light

Futura Demi Bold

Futura Medium

Futura Bold

The demibold or bold form is preferred by many readers with low vision. However, caution should be used when you choose bold type. Some readers may have difficulty with this type weight, because they may perceive the heavy black letters as bleeding into each other. The old rule that the darker and thicker the letter, the easier it can be read is no longer a criterion. Good contrast between the ink and the color of the paper on which it is printed, the density of the ink, and the selection of a paper with a surface that does not reflect light are important elements to consider. Persons with impaired vision can use magnifiers, closed-circuit televisions (CCTVs), and the like to enlarge the text. However, no reader is like

another, with or without such aids. It is important that the producer of a display know about optical devices and the extent of the reader's impairment and use of these aids.

Italic and Cursive Styles

Italic is a type style in which the letters slant to the right. Cursive or script is a type style in which the letters are joined with rounded angles.

Girder Bold Italic *Typo Script*

Italics are often used in print to emphasize particular words or sentences. The same is true of uppercase (capital) letters or of underlined words. Avoid using these styles. To gain emphasis, increase the weight (not the height) of the letter, word, or sentence.

Type Sizes

Type is measured by what is known as the point system, which is based on the division of the inch (2.5 cm) into 72 equal parts or points. What is legible type size for a reader depends on the limit of the reader's vision and whether he or she relies on the use of low vision aids. Nolan (1959) stated that 18-point type may be more legible than larger or smaller type sizes for the majority of students with low vision.

The 18-point type size is unnecessary for those persons who read with a magnifying aid. For such persons, 11-point to 14-point type seems sufficient (Swedish Federation of the Visually Handicapped, 1983). Elderly people with limited vision and small children who are learning to read, however, may need the larger size type in their displays. Examples of various type sizes are shown here.

ABCDEFGHIJKLMNOPQRSTUVWXYZ& FUTURA DEMIBOLD • 10 POINT

ABCDEFGHIJKLMNOPQRSTUVWXYZ& FUTURA DEMIBOLD • 12 POINT

ABCDEFGHIJKLMNOPQRSTUVWXYZ& FUTURA DEMIBOLD • 14 POINT

ABCDEFGHIJKLMNOPQRSTUV FUTURA DEMIBOLD • 18 POINT

Additional Considerations

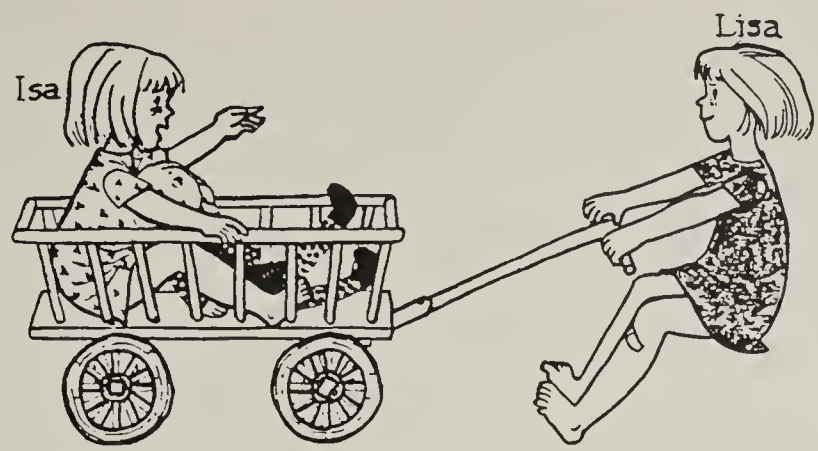
- *Size of letters.* Many readers prefer a text that combines capital and small letters. They find it easier to read than text consisting of capital letters alone.
- *Spacing of letters.* The distance between words should not be too long or too short. This distance should mark the end of one word and the beginning of the next without losing the reader along the way. Approximately 1/16 in. (2 mm) between words seems to be adequate. A beginning reader often sounds out each letter as it comes within the line of focus of his or her low vision aid and does not experience the word as a unit. Therefore, a definite space between words is necessary. Avoid hyphenating words. Split words may be difficult for the reader to understand, and it is hard enough for him or her to try and piece together all the components of a display without having to deal with yet another visual task.
- *Length of a line of type.* Line length is also governed by the specific needs of the reader. Avoid long lines of type. In general, short lines do not usually require a great deal of eye movement, and the reader therefore does not run the risk of losing his or her way from one line to the next. Acceptable lengths of lines of type range from a minimum of 2.2 in. (5.5 cm) to a maximum of 4.4 in. (11.3 cm).
- *Distance between rows of text.* The white space around a letter, word, sentence, or line is as important as the weight and size of the text itself. This space is regulated by the size of the type that is used. If the lines of type are too close together, the reader's eyes may have trouble moving from the end of one line to the beginning of the next. A 12-point type may need a 12-point distance between lines, and an 18-point type may need 18-points. Be aware that too much space between rows of type also makes reading more difficult.
- *Display size.* The size of the display is important. Some readers have a very confined field of vision. Check your reader's visual field before planning your display. A relatively small display size, 6 in. to 12 in. (15 to 30 cm) allows reader control as he or she focuses on the various parts of the display. The reader will not have to scan the display unnecessarily in order to recognize shapes and their relationships.

EDITING A GRAPHIC DISPLAY

The illustration of Mina and Karo and Tore, Lena, and the other children shown here from *Nu Laser Vi, Laseboken A* (Boorman, Matthis, Salminen, and Wigforss, 1977) is difficult for the reader with low vision to understand. He or she experiences it as utter confusion, even when viewing the original version, which was printed in clear colors. The people in the picture are important to the story and should not be left out of the book. Therefore, some changes must be made.

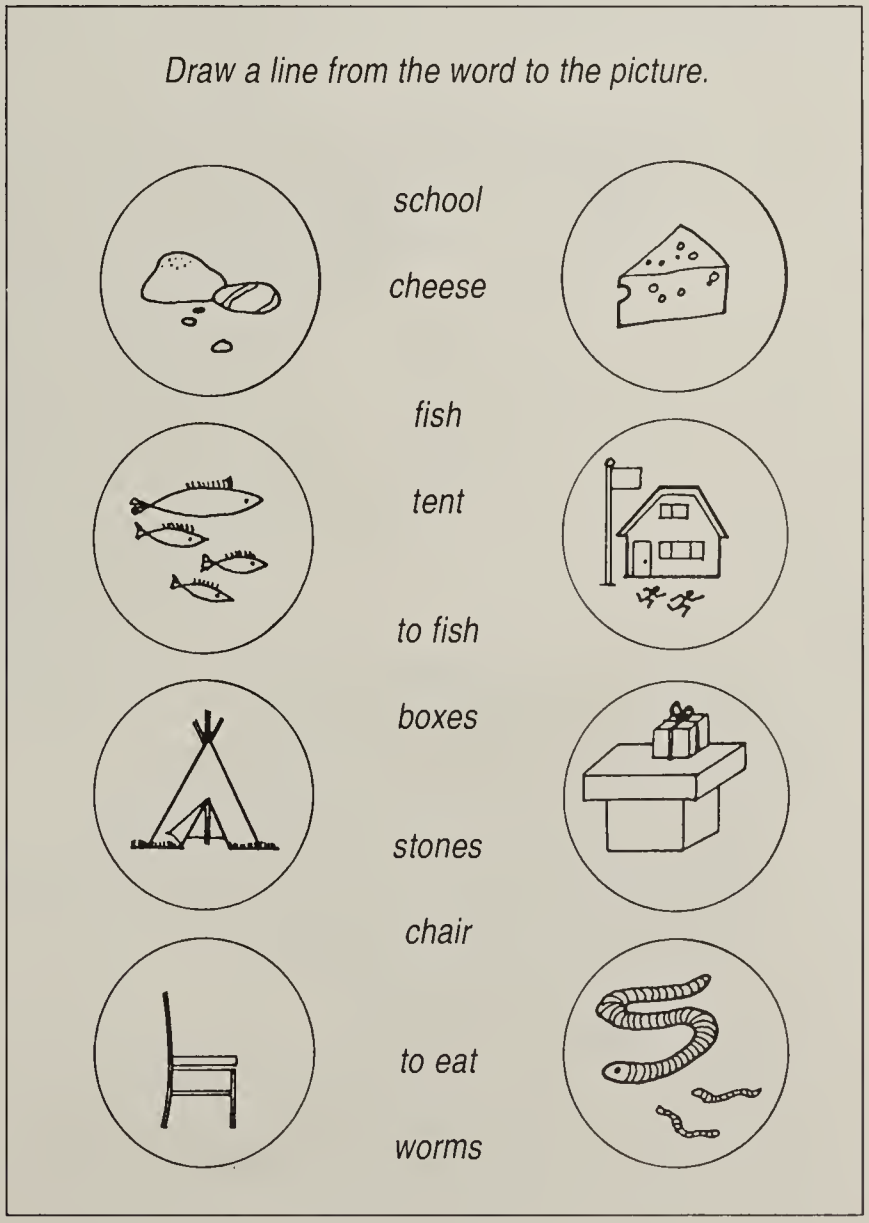
An illustration that many low vision readers will find confusing.

Cut out or paint away individual figures. Strengthen the lines around the figures so that they are outlined against the background. You can present several figures at a time, as shown at the top of the next page, but not all of them at once.



Isolating some of the figures in a crowded illustration will make them more understandable.

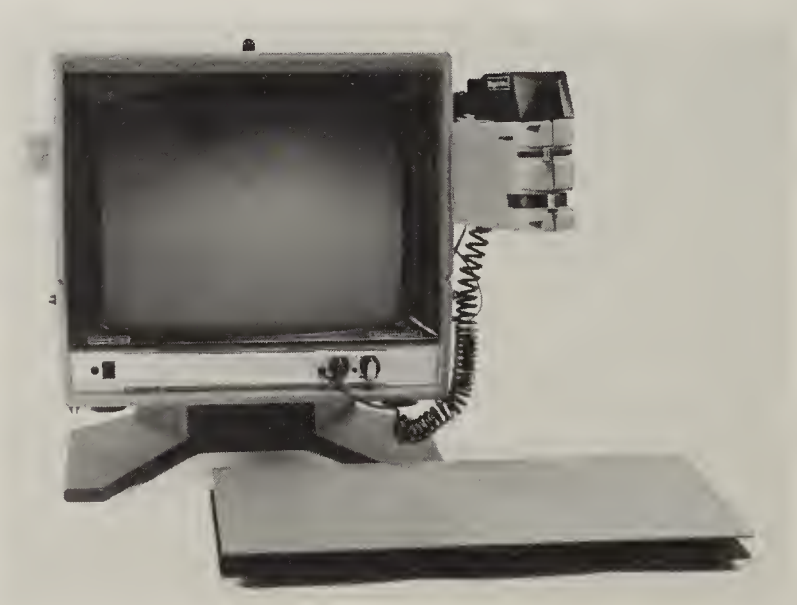
When preparing materials for low vision readers, keep in mind that certain tasks, such as drawing lines to connect pictures and words, are difficult or awkward for the reader who uses a magnifier, CCTV, or other enlarging device. The reader's pencil will often be out of the line of focus, his or her hand may cover part of the display, or there may be another similar problem. If the illustrations in the matching exercise shown below were numbered, the reader could write the answers on a separate sheet of paper and avoid these problems. Simple changes in materials can make them easier to use by the reader who depends on low vision aids.



DEALING WITH SIZE REQUIREMENTS

The CCTV unit shown below is the Magnilink System 402, produced by Low Vision International (see "Sources of Materials and Equipment," Appendix 3 for address). It is a magnifying aid for visually impaired persons. It consists of a 17 in. (43.2 cm) monitor and a camera with an optical head. The camera unit can be mounted on either side of the monitor (as shown here), on an arm, or on a worktable, or it can be used as a hand model. The monitor enables the reader to view text that is enlarged 5 to 30 times its normal size. Another excellent CCTV system is the TeleSensory system available in the United States from TeleSensory of California (see Appendix 3 for address). The 12 in. (30.5 cm) monitor magnifies up to 45 times the original size of the printed material; the 19 in. (48.3 cm) monitor enlarges material up to 60 times its original size. Despite the magnification, students working with such machines may find that they have a problem with pictures—not because of the machine but because of the educational material that is available. Often, students are unable to see a complete illustration, page in a textbook, or map. They can instead see only part of this greatly magnified material at one time. An object out of context is difficult to comprehend, especially if the map or picture is new and unknown. Consequently, students have difficulty fitting these parts or pieces together to understand the entire layout.

Map study is particularly complicated. Size relationships between countries, or within a single country, never appear on the screen of a device like a CCTV unless special maps are created to fill the entire magnified area of the screen. Details on these maps can be studied when the television camera is



Magnilink System 402.

focused (zoomed in) on a particular area after the student has had time to understand the map or picture as a whole form. Thus, students with low vision need maps that are just big enough to fit the television screen when fully magnified.

To find the correct display size in such a situation, place white paper on the worktable below the camera unit of the machine. Draw outlines of rectangles on the paper until you find one rectangle that fills the entire area on the television screen (in the case of the Magnilink shown on the previous page, the size was 2 in. by 2.7 in. [51 mm by 69 mm]). The size may vary, depending on the type of CCTV you use.

Other elements and methods can be used to adjust for size. For example, I have placed a simple map of Europe in a reprocamera (see "Enlargements and Reductions," Chapter 7) and reduced it to fit within an area measuring 2 in. by 2.7 in. (51 mm by 69 mm). The reprocamera method ensures sharp lines in the copy, in contrast to the quality of lines obtained from some office copying machines. Sharp lines are hardly noticeable in a reduced display. However, the quality of lines becomes obvious when the student enlarges sections of the map to study details. Lines from some copy machines have a "furry" character when magnified.

The map of Europe shown here was part of a miniatlas project that was intended to contain maps of all the countries of Europe. The original map was reduced in size and the

textured water painted black. Minimaps are still in the experimental phase. The black background used in this map was based on the fact that many of the low vision students tested in Sweden during the 1980s preferred reading white letters on a black or dark background. Maps with dark outlines and contrasting areas of land and sea or a contrasting texture or color around a particular country seem to be the easiest to read on a screen or through all types of magnifying devices.

Teachers who knew about the miniatlas project have already requested a map sheet of the tiny map of Europe. The sheet that was planned would have contained nine copies of the same map. Teachers could have cut out a map when it was needed and painted the country being discussed in class that week.

Many variations of the minimap can be made. Although this concept is still in the research stage, it has been presented to show you that there is a solution to most problems. Keep an open mind. Listen to your readers. Their comments can often lead you to an unexpected solution.

COLOR

The use of color in displays for visually impaired people is a vital but undeveloped field. Although several research programs are in progress, little has been written on the subject. Therefore, the producer who needs to know which colors to use on maps and pictures has few references as guidelines.

If the tactile display is for blind readers, the issue is simple: Color should be transformed into relief textures. Maps, however, present a different problem if they are to be used in the field by blind and visually impaired persons alike. The use of black printed text on a white relief map makes it easier for a sighted person to help a blind traveler. A black-and-white map, such as those produced on microcapsule paper, is an even better solution to aid communication between people with different levels of vision. For microcapsule paper maps, black text can be written directly on the map beside the braille text *after* the map has been swelled. If this is done before the map is heated, both areas will swell, which could result in confusion for the blind reader, who is unable to interpret the inkprint letters.

In regard to color, it is also interesting to note that the worldwide effort to integrate blind children into schools formerly attended only by sighted children has resulted in the wider use of colored foaming inks (see "Silk Screening," Chapter 2) and the silk-screening process in the manufacture of relief books that can be read by everyone.

The majority of visually impaired persons have some useful sight. Their ability to see with the aid of eyeglasses, magnifiers, CCTVs, and the like varies considerably, as do their attitudes toward their visual impairments. Many persons feel that because they have some vision and therefore are not totally blind, they do not need relief materials made for blind persons. No matter how good the relief material may be or how much color has been added to it, they may regard it as material for blind persons and not for themselves.

This attitude may pass, or it may not. Some children have overcome feelings in this area by actively changing the relief material given them—by adding color with felt-tipped pens or paint, by cutting out materials and gluing them to the displays, or by making routes and streets on maps with tape.

Relief material can be useful if sight depends more on fingers than on eyes, but it is not the solution for all visually impaired persons. People with low vision should have those materials best suited to their situation and needs. As a producer of material, try to know your readers. One simple way to put yourself in their place is to simulate their visual impairments. Tape several layers of transparent plastic from bags, loose-leaf folders, and the like over the lenses of a pair of eyeglasses. Your vision will be as limited as the number of layers and the clearness of the plastic you use determine. This is an excellent way to experience color as your readers see it. You will clearly note if the colors you have chosen have good contrast. (This experiment was developed by the Tomteboda Resource Center for Visually Handicapped Children and Young People in Solna, Sweden, in 1986.)

Contrast is the most important element to keep in mind for displays for the low vision reader. Tests carried out in Sweden by the Swedish Federation of the Visually Handicapped indicated that black text on white background is the most effective contrast for people with low vision. Colored layouts in schoolbooks, magazines, and newspapers in which text is

printed on a colored area are very difficult to read because of the decrease in contrast between text and background. If colored emphasis is necessary in a display, use a colored frame around your text area.

Choosing colors can be confusing for sighted people because they are used to experiencing different colors and are not aware of the contrasting values of colors. They automatically separate these colors into forms and objects. For the low vision observer, these forms may melt together into a milky picture in which no contrast or obvious forms are seen.

An easy way to check color contrast is to copy your colored material or small samples of colored paper, paint, or color from felt-tipped pens in an office copying machine. These examples will show that different colors have different degrees of lightness or darkness. The illustration shown on the next page, a color chart that has been copied in an office copying machine, points out which colors contrast with one another. You can choose contrasting colors by seeing which stands out against the other.

Different copying machines may give different results because of the various filters or lights that are used in these machines. Therefore, it is preferable to test your colors in several machines before you make a final decision.

For low vision readers with impaired color perception, it is best to avoid using red and green together in the same display. Check your readers' color problems, if possible.

Other Considerations

Paints, papers, plastics, and printed materials that are used by people with low vision should not have a glossy surface--a surface that reflects light. The glare of a shiny surface under a bright light may make it impossible for them to see what is before them, no matter what paper or colors are used.

You should take into account the reader's use of visual devices as aids when considering the use of color on a graphic display. For example, many people rely on a CCTV to magnify their reading matter. With these machines, a reader can usually choose to read black text on a white background or white text on a black background. If you are producing material for a reader who uses the white-on-black system, of

White
Putty gray
Sulphur yellow
Ice blue
Light pink
Arctic green
Cream yellow
Gray-blue
Orange
Olive green
Lemon yellow
Emerald green
Coral red
Royal blue
Golden yellow
Bright blue
Brick red
Mustard yellow
Lime green
Copper brown
Baby blue
Coffee brown
Sand brown
Steel gray
Bronze yellow
Black

Color samples reproduced on an office copier to check for contrast.

Clear colors

Blue *Yellow* *Red* *Brown* *Green*

what use is a colored display? However, the latest machines do provide for color viewing with the possibility of increasing or decreasing the contrast of the colors. These machines can also be used for black-on-white or white-on-black viewing.

When creating displays, another question to ask is, Does the color used in the textbook add to the picture or map? Is it easier to read because of the color? Or is the color a way of making the book more attractive? Would a line drawing of the same illustration be more effective for your reader, especially if he or she studies the material on a black-background television?

Textbook material can often be used in its original form if it is simple and uncluttered. Otherwise, redraw the illustration or strengthen lines, remove unnecessary lines and objects with white paint, and add contrasting color when necessary. A photograph, with its many gray tones, may be more difficult for the reader to understand than a good drawing.

Relief Materials and Color

A highly effective and economical method for adding color to a small quantity of plastic relief displays is to use felt-tipped pens made for use with overhead film or paint made for use with model plastic cars and airplanes. Outline the main features of your display with a dark line, or fill in the areas of your map or picture with solid color. Yellow seems to be a color that can be discerned by most people with limited vision. For many readers, clear primary colors are sufficient; for others, contrasting colors are prerequisite.

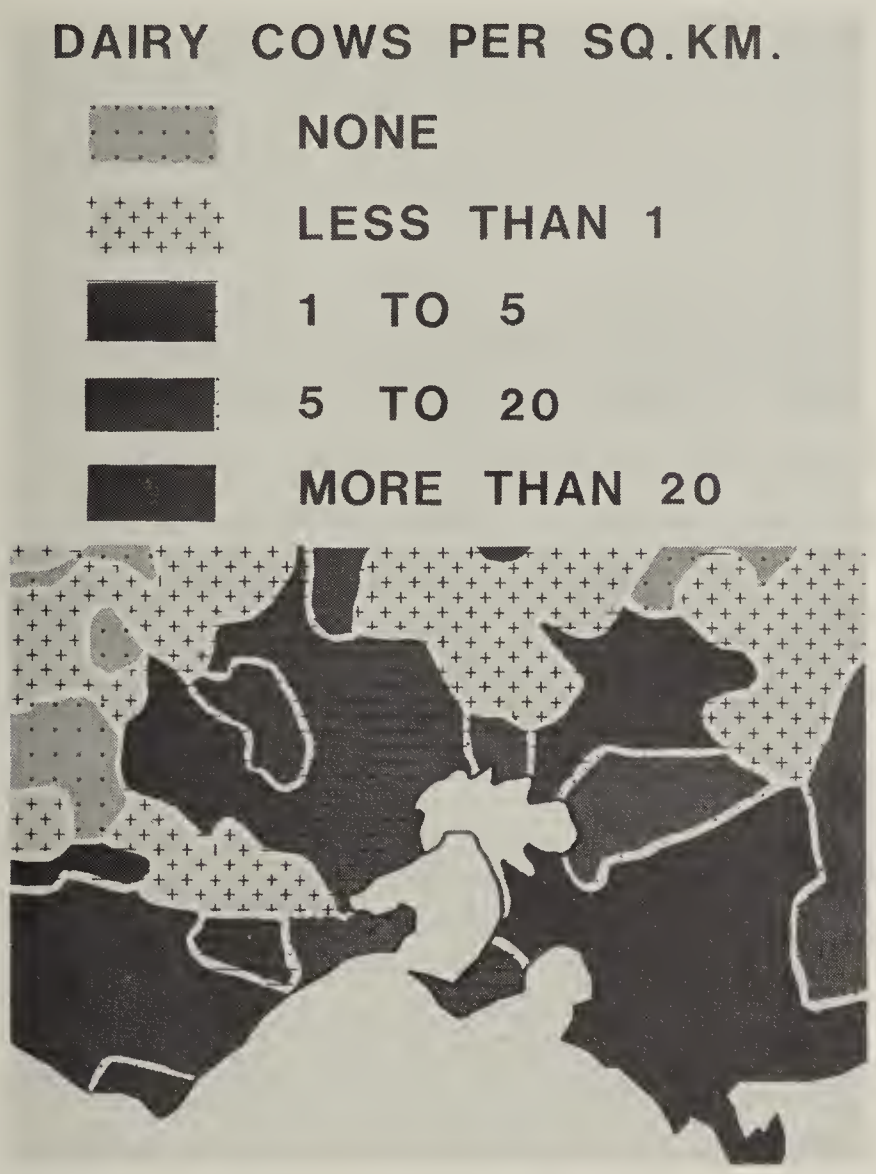
Poster paint or ordinary felt-tipped pens work well for adding color to microcapsule paper maps or pictures. Remember that the surface of this paper is covered with microcapsules; test the color to be used on a sample piece to be sure that it does not dissolve the paper's coating.

The print map shown on the next page (see A) was printed in a four-color process on white paper and used yellow, blue, red, brown, and black. Brown is a combination color made by mixing red, yellow, and blue printing inks. Although the map contains much information, it is simple and easy to understand. White lines outline each colored area, and the text is large and easy to read. The map was produced as part of an Australian

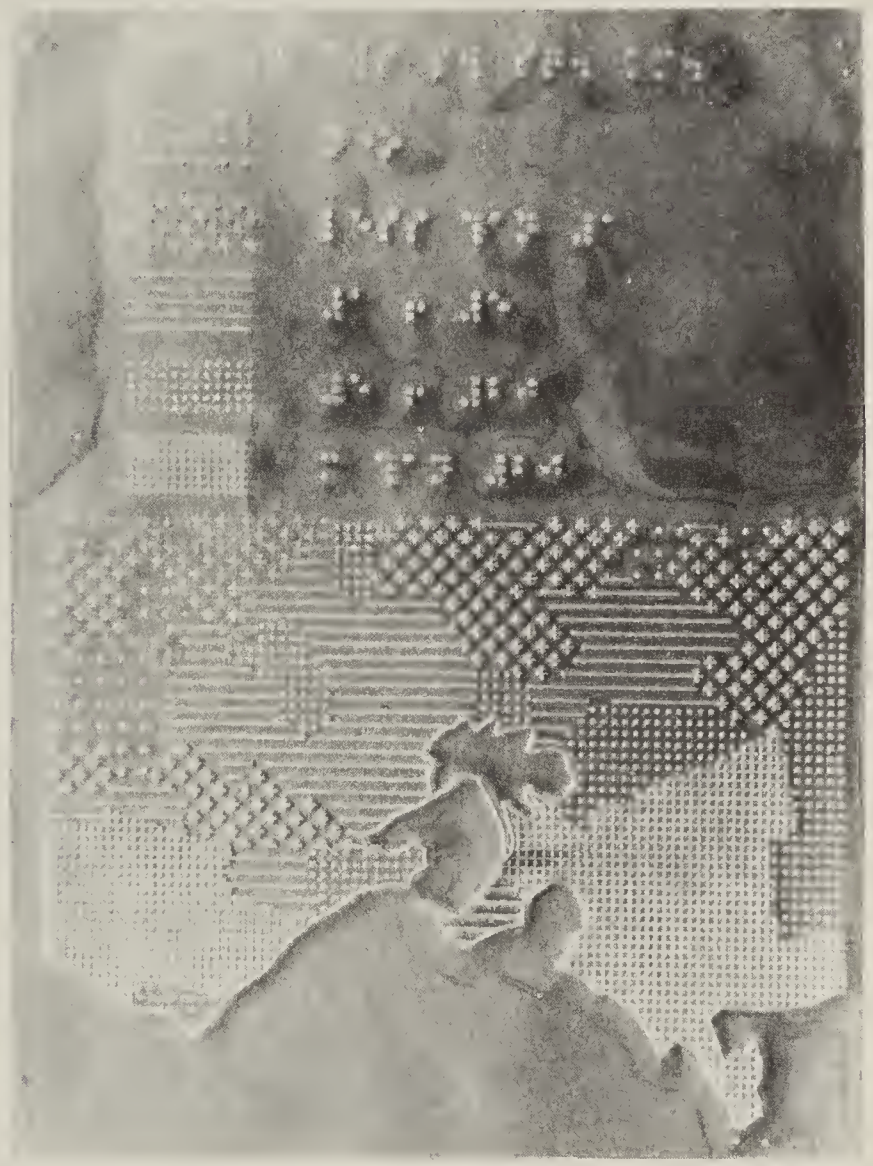
project to make maps for readers with low vision, who are blind, or who have unimpaired sight.

The relief map also illustrated here (see B) is an exact copy of the printed map. It is made from colorless transparent plastic. Each colored area has been transformed into a relief texture. The text has been transposed into braille.

A colored display for all types of readers, consisting of a printed and a relief map that can be used separately or together.



A.



B.

A solid relief line between the various textured areas on the relief map that corresponded to the white lines on the printed map would have made it easier for blind readers to understand the boundaries of these areas. However, since this is one of the few maps of this kind, this is a minor element on which to comment. The main point is the possibilities that this type of map offers to producers who are not able to silk screen or print on plastic before it is vacuum-formed into a relief map but who

still want a map that can be read by the majority of visually impaired persons.

In the final step, the relief map is placed on top of the printed map and fastened in place. The maps can be used together or separately. Once the master is made, the plastic copy can also be made in white plastic and transformed into a black-and-white version by painting the boundaries black.

Another version of this relief/print process is to take a master of a map or picture that was produced in white plastic and copy it in transparent plastic in a vacuum-forming machine. Redraw the original master sketch with black ink and make several copies of it in an office copying machine. Paint these copies with colored paint. Mount the colored and transparent copies together. This process is appropriate for producers who want several relief/print maps but who do not have access to or money for color printing. (For more information about the combined relief/print map, write Graphics Research for the Blind, Department of Geography, University of Melbourne, Parkville, Victoria 3052 Australia.)

CONCLUSION

Graphics for people with low vision is a difficult area to discuss, mainly because of the great variety of factors involved. Each person's sight is different, and what he or she sees or does not see is a personal experience that is based not only on the degree of vision the person may have but also on the aids and machines he or she may be using and the amount of light that falls on the object that is being viewed. Even the reader's physical or mental state at a particular moment can influence the reception and comprehension of a printed image.

Your task, to produce workable graphics for readers with limited vision, is not as clear-cut as that of making materials for completely blind students. Granted, there are many similarities, for example, the use of such elements as simplicity, bold outlines, strong contrasts in area texture, and step-by-step illustration series. But there are the added choices concerning colors and decisions about the size of the material to be made. If the distance between the layout and the student will only be a nose length, then a large display should be reduced in size to allow the reader to understand the complete form of

the area at the end of his or her nose. Another consideration is the choice of paper or plastic on which the graphics will be printed. The amount of glare, or reflected light, from a glossy surface can turn a good display into a blinding experience.

The use of color is an advantage for the reader with low vision, but it can also be a drawback. Too many unrelated color areas in a display can be confusing and distracting. Remember, it is the information that you are giving the reader that is most important, not a lot of extraneous shapes, lines, and colors that make a nice-looking layout. People with reduced vision have a difficult enough time trying to understand the content of the display; make this process as easy as possible for them by producing simple, uncluttered layouts with high-contrast content. Use your imagination and your plastic-covered glasses. Do not accept the easy way out by reproducing an illustration that you hope will work. Try to put yourself in your reader's place!

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CHAPTER 10

Evaluation of Relief Material

Conversations with visually impaired readers are the best way to find out whether your material works as you intended it to. Be both clear and diplomatic in asking questions, so that you derive useful answers and readers understand that you are interested in the effectiveness of the relief material and are not questioning their ability to use it. Without contact with readers, you may stagnate. How can you know if your tactile displays, seen through your eyes, are delivering the same information at the same unhindered rate through your readers' fingers?

Talk with blind readers and their teachers before and after you produce various types of materials. If it is possible, visit schools where your displays are being used. Listen and react to classes in session. Contact with teachers is invaluable and can do much to promote a clear understanding of how materials can be used. This interaction can be especially important in integrated schools, where some regular classroom teachers may be unfamiliar with relief material and the ways in which it can or should be used. Whenever you can, tell the teacher, verbally or in written instructions, just what you intended to achieve with your material and how it could be used in connection with a textbook or in classroom work. Information should also reach the students. Putting material in their hands and assuming that they can read it does not ensure that they can understand it, and if they do not understand it, they will not want to use it. No matter how excellent your relief material may be, it cannot be of much use if it lies on a shelf.

Personal contact is ideal but is not always feasible. Written

OPPOSITE PAGE: The most effective way to evaluate relief material is by talking to the readers who use it.

contact is second best. Included in this chapter is a questionnaire that I have sent along with material I made for schools that I was unable to visit. The questions can be answered quickly, and the comments are of utmost importance to future productions because they provide insight into the reactions of individual students.

The sample questionnaire at the end of this chapter is only one way to construct a questionnaire. I hope that you will write your own questions, ones that are suitable for gaining the greatest amount of useful information from your readers. A questionnaire may not be the answer for you. However, evaluation is necessary, and it should be carried out in some active manner.

The demand for tactile graphics from persons outside educational systems has tripled within the past few years. The increase in requests for maps seems to follow the increased interest in world events. People want to know where things are happening. A map can help the reader put events in their geographic place and illuminate their relationship to the reader's own country. As the demand for relief materials increases, comments and suggestions from users of these materials will naturally increase. What better evaluation can a producer hope for than the reactions of his or her public?

Andrew Turk from the Division of National Mapping, Victoria, Australia, has noted that the producer of graphic displays needs to examine the factors that influence the success or failure of tactile graphic communication. He commented that "it is all too easy to become engrossed in the detail of one particular element of the process and lose sight of what we are trying to achieve. What ultimately matters is the change which occurs in the mind of the person using the graphic" (1988). To that, factor in your ability to translate your reader's actions and thoughts into more understandable, more easily read relief displays. There is a solution to each situation, but it may not be the same solution that you have used before. Making tactile graphics is a challenging and ever-changing occupation. It depends on old theories, new ideas, and the availability of different materials. But most of all, it depends on the information that you and your readers receive through your fingertips—information that you are able to develop together and pass on to an ever-widening circle of users of tactile graphics.

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Turk, A. (1988, April). Comments made during the Symposium on Tactual and Low Vision Mapping, International Cartographic Association, London, England.

SAMPLE QUESTIONNAIRE

Evaluation of tangible graphics for visually impaired readers

Title and catalog number of the book or page

.....

Author .....

Student's name and class .....

.....

School .....

Address .....

Telephone number .....

Date .....

(Continued)

	Yes	No
Is the student familiar with relief material?	❑	❑
Maps	❑	❑
Pictures	❑	❑
Does the student use relief material?	❑	❑
Often	❑	❑
Seldom	❑	❑
Is this relief material used in conjunction with three-dimensional objects?	❑	❑
Is this material used by the visually impaired student at the same time as his or her classmates are using similar printed material?	❑	❑
Can the student read and understand this material without help?	❑	❑
Is this relief material used by sighted students as a complement to their printed pictures and maps?	❑	❑
Does this material need a more complete braille description?	❑	❑
Is the material too complicated for the student?	❑	❑
Should this material have been presented on more than one page, with less information on each picture/map?	❑	❑
Is there too much information on this map/picture?	❑	❑
Or too little information?	❑	❑

		Yes	No
Can the student identify	Water?	❑	❑
	Land?	❑	❑
	Borders?	❑	❑
	Rivers?	❑	❑
	Mountains?	❑	❑
	Cities?	❑	❑
	Other symbols?	❑	❑
	Numbers?	❑	❑
Are the different textures in the picture/map confusing?		❑	❑
Are the textures difficult to tell apart?		❑	❑
If so, can you state which ones?			
.....			
Are there too many textures in one picture/map?		❑	❑
Are the line symbols in the picture/map confusing?		❑	❑
Are the line symbols difficult to tell apart?		❑	❑
If so, can you state which ones?			
.....			
Are there too many line symbols in one picture/map?		❑	❑
Can the student understand the symbols that are used?		❑	❑
Are any of the symbols confusing?		❑	❑
If so, which ones?			
.....			
Are there too many symbols in the picture/map?		❑	❑

	Yes	No
What is your opinion about the arrows in the display? Are they helpful?	❑	❑
Can the student follow the arrows?	❑	❑
Should the arrows be larger?	❑	❑
Smaller?	❑	❑
Should the shaft on the arrow be longer?	❑	❑
Shorter?	❑	❑
Is the key understandable?	❑	❑
Is the key complete?	❑	❑
If text is used in the picture/map, is it well placed?	❑	❑
Should there be more text?	❑	❑
Should there be less text?	❑	❑
Is the text written in the right direction?	❑	❑
Can you feel the difference between the text and texture?	❑	❑
Can you tell the text from the symbols?	❑	❑
Is the picture/map informative?	❑	❑
Is it unnecessary?	❑	❑

Further comments.....

.....

.....

Thank you for your help.

Appendixes

APPENDIX 1

Basic Materials Used in Making Displays

Tactile graphic displays can be made out of a tremendous variety of materials and with a great variety of techniques. The following is a listing of some of the basic materials and tools and the equipment that producers of displays commonly use.

PENCILS, PENS, AND PAINT

Ballpoint pens, for working on raised-line drawing boards.

Black ink, to use with a paint brush or in inking pens. Find the ink that is best suited to your inking pens.

Erasers (rubber and plastic).

Fiber and felt-tipped pens, for working directly on drawing paper and microcapsule paper. Some permanent-color pens work well on plastic copies of maps and pictures for readers with low vision.

Lead pencils and leads for mechanical pencils (grades 2H, HB, B, 2B).

Paint, white and nonbleeding colors, for editing inkprint originals or covering unwanted ink lines. Colored paint for plastic hobby models is excellent for use on plastic displays for low vision readers.

Paint brushes, to use with ink or paint (inexpensive brushes for use with glue and shellac). Brush numbers 1 and 2 are good sizes for editing original displays; larger brushes are needed for painting displays for low vision readers.

Technical or inking pens that produce an even line. Point widths: .005 in. - .08 in. (.13 mm -2 mm). Most useful widths: .005 in. (.13 mm), .01 in. (.25 mm), .014 in. (.35 mm), and .02 in. (.50 mm) for microcapsule paper originals.

COATINGS, GLUE, AND TAPE

Glue, transparent, to use with paper, wood, leather, and the like. Be sure it is heat resistant and can be used in a vacuum-forming machine.

Putty, a type of stiff paste or cement for filling cracks, sold commercially, often in tubes. Useful for protecting braille characters and some relief areas from heavy use. Spread thinly with a spatula on the back of the display's sensitive area.

Shellac, for protecting cardboard or paper edges from splaying, fragile surfaces from deteriorating, and tiny elements from becoming unglued from their background material.

Spray glue, for mounting textured areas onto a display, used with embroidery canvas, crepe

paper, and other fragile materials that would otherwise lose their shape if glue were applied by any other method.

Tape, transparent tape for all-around use; double-backed or double-sided tape for mounting parts of a display that cannot be glued to the background; and drafting tape for attaching drawings to a drawing board temporarily to work on them. White correction tape is also useful for editing drawings and printed graphics; it is available in two widths, .33 in. (8.38 mm) and 1 in. (25.4 mm), from the 3M Company (see "Sources of Materials and Equipment," Appendix 3 for address). Binding tape is used for joining several sheets of paper or plastic in foldout displays. Micropore 1535, a porous medical tape, has been well tested for this purpose. It is available in two widths, 1 in. (25.4 mm) and .4 in. (10 mm), from the 3M Company.

KNIVES, SCISSORS, AND HOLE PUNCH

Hole punch, useful for making holes in paper, cardboard, leather, and plastic and for making circles of different sizes to be used as symbols. Several hand punches with different size holes can be used, or one hand punch with a rotating head that is capable of making several different sizes of holes.

Knives, for cutting and shaping different materials, such as wood, Styrofoam, cardboard, and plastic. Blades for hobby knives frequently are sold separately from the handles and come in sets of 5-15 per package. Scalpels are also often packaged with one handle and separate blades, which are sharper and have more even edges than hobby knives. Additional packages of one type of blade are also sold.

Pinking shears, useful for making zigzag edges on woven materials and paper and for creating textured areas made by gluing one zigzag strip on another.

Scissors, large and sturdy enough to cut plastic, aluminum foil, lightweight tin, heavy paper, and cardboard. Smaller scissors are useful for cutting paper, string, and woven materials and for doing more intricate work.

Spatula or palette knife, a knife with a thin, flexible steel blade but no cutting edge. Used for spreading glue or putty and for loosening or lifting material from backgrounds.

MEASURING IMPLEMENTS

Divider, a type of compass that can be used for quickly measuring the same distance several times without using a ruler each time. Essential in layout work.

Drawing compass, which can be used with inking pens or a pencil lead. It should have an extension arm that will enlarge by 25-50 percent the circular area it can circumscribe.

French curve, for accurately drawing complex curves with an inking pen. Draw part of the curve, using the guide, then move the guide to another position and continue the curve as desired.

Stencils, for making arrows, circles, and ellipses. Made of transparent plastic to be used with inking pens. There are many different kinds and shapes. You can cut your own stencils from a sheet of plastic with a scalpel. Add small bits of cork or cardboard to the underside to raise the plastic enough to use it with an inking pen.

Transparent ruler, with inches, centimeters, or both, about 25 in. (63.5 cm) in length. It is advantageous if one edge is a cutting edge and the other edge is raised to accommodate the use of inking pens.

Transparent triangles, one 45° and one 30°-60°. The triangles' edges should be indented so they can be used with inking pens. An inch or centimeter scale that is engraved along one edge of the triangle is also an advantage.

T Square, for drawing straight horizontal lines, used on a drawing board or other flat surface with a straight edge so that it can glide back and forth. A raised edge for inking pens is desirable.

TOOLS FOR BRAILLE AND FOR EMBOSSING

Embossing tools, for embossing braille paper and aluminum foil. These include ballpoint pens, wooden sticks, nails, and spur or tracing wheels of various sizes.

Freehand drawing stylus, which often comes in two sizes: standard braille dot and jumbo dot.

Rubber pad or raised-line drawing board, for embossing paper or metal foil.

Slate and stylus, for writing braille without a machine. Usually available in three sizes for jumbo braille, standard braille, and microbraille.

MACHINES AND OTHER EQUIPMENT

Braillewriter, for writing braille mechanically.

Large-print labeler, which prints embossed letters on tape. Necessary only for large-print displays.

Office copying machine and an infrared fuser, necessary for making microcapsule paper displays.

Paper cutter, preferably one that is self-sharpening.

Vacuum-forming machine, for producing plastic copies from an original master.

PAPER AND OTHER MATERIALS

Aluminum foil, available in rolls or sheets.

Braille paper, a sturdy paper that will retain an embossed impression after much use. Can be used in a braillewriter, with a writing slate and stylus or embossing tools, or for making paper-on-paper displays.

Cardboard of various thicknesses, for making displays.

Embroidery canvas, for background material as well as textured areas.

Sandpaper of different grades of coarseness.

Semitransparent drawing or **drafting paper** or nonoily, nonwaxy baking paper that will allow you to see through several layers of drawings at the same time.

Small nails, rubber bands, a hand stapler, wire, upholstery nails, brass paper fasteners, and paper clips.

Small needles, for sewing and for making holes in background material when a display is to be used in a vacuum-forming machine.

String and thread of various sizes and thicknesses.

BOARDS AND BOXES

Drawing board, a large rectangular board for making drawings with a T square and triangles. Floor models and models with adjustable tabletops are available. Some boards are equipped with movable T squares.

Light table or light box, a structure with a flat surface and squared-off edges, whose top surface can be illuminated from below. Also called a light board, it is useful for preparing microcapsule paper displays, as well as patterns for single designs or masters for mass production. A light table is also a drawing board and can be used with a T square and a triangle. Available in tabletop or floor models.

CONVERSION FACTORS

In using the materials and techniques discussed throughout this book, the information and conversion factors that follow may be helpful.

To convert measurements in metric system units to inches, use the following formulas:

millimeters x .0393701= inches
centimeters x 0.39370 = inches
meters x 3.280840 = feet
meters x 1.09 = yards

To convert measurements in inches to units in the metric system, use the following formulas:

inches x 25.4 = millimeters
inches x 2.54 = centimeters
feet x 30.4800613 = centimeters
feet x 0.3048 = meters

To convert Celsius (Centigrade) to Fahrenheit, multiply by 9, divide by 5, and add 32. To convert Fahrenheit to Celsius (Centigrade), subtract 32, multiply by 5, and divide by 9.

TABLE 1. Standard Paper Sizes[a]

Type	Size		Type	Size	
	In Inches	In Millimeters		In Inches	In Millimeters
Metric (trimmed sheets)			*Imperial (untrimmed sheets) (continued)*		
A0	33.11 x 46.81	841 x 1189	Crown	20 x 15	508 x 381
A1	23.39 x 33.11	594 x 841	Foolscap	17 x 13 1/2	432 x 343
A2	16.54 x 23.39	420 x 594	*Standard U.S. (untrimmed sheets)*		
A3	11.69 x 16.54	297 x 420	Bond/writing size	24 x 38	610 x 965
A4F	10.25 x 11.75	260 x 298		17 x 22	432 x 559
A4	8.27 x 11.69	210 x 297	Book Size	22.5 x 35	571 x 889
A5	5.83 x 8.27	148 x 210		20 x 26	508 x 660
Imperial (untrimmed sheets)			*Japanese (trimmed sheets)*		
Double crown	30 x 20	762 x 508		11 x 14	257 x 364
Royal	25 x 20	635 x 508		7 x 11	182 x 257

[a]Depending on their applicability or use, large sheets should be cut in half.

APPENDIX 2

Sources of Information

A wide variety of organizations disseminate useful information, provide materials that may be used in the production of tactile graphics, and produce specialized materials for blind and visually impaired persons. This appendix contains a sample list of organizations that can offer information and assistance to producers and users of tactile graphics. Organizations in the United States that do not appear in the listing that follows may be found in the *Directory of Services for Blind and Visually Impaired Persons in the United States, 23rd edition*, published by the American Foundation for the Blind (1988).

American Foundation for the Blind
15 West 16th Street
New York, NY 10011
USA
(212) 620-2000 or (800) 232-5463 (Hotline)

The American Foundation for the Blind (AFB) provides a wide variety of services for blind and visually impaired persons and their families, professionals in specialized agencies for blind persons, community agencies, organizations, schools, and corporations. AFB also provides legislative consultation; operates the M. C. Migel Memorial Library, a special reference and lending library on blindness; publishes books, monographs, and periodicals in conventional print and braille and in recorded forms; manufactures Talking Books; develops, manufactures, and sells special devices and equipment for use by blind persons; and disseminates information about the latest technology available for blind and visually impaired persons through its National Technology Center. AFB operates a toll-free information hotline and maintains the following five regional centers across the United States:

Eastern Regional Center
1615 M Street, N.W., Suite 250
Washington, DC 20036
(202) 457-1487

Serves Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and Virginia.

Midwest Regional Center
20 North Wacker Drive, Suite 1938
Chicago, IL 60606
(312) 269-0095

Serves Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, North Dakota, South Dakota, and Wisconsin.

Southeast Regional Center
100 Peachtree Street, Suite 1016
Atlanta, GA 30303
(404) 525-2303

Serves Alabama, Florida, Georgia, Mississippi, North Carolina, Puerto Rico, South Carolina, Tennessee, the Virgin Islands, and West Virginia.

Southwest Regional Center
260 Treadway Plaza
Exchange Park
Dallas, TX 75235
(214) 352-7222

Serves Arkansas, Colorado, Kansas, Louisiana, Montana, Nebraska, New Mexico, Oklahoma, Texas, and Wyoming.

Western Regional Center
111 Pine Street, Suite 725
San Francisco, CA 94111
(415) 392-4845

Serves Alaska, Arizona, California, Guam, Hawaii, Idaho, Nevada, Oregon, Utah, and Washington.

American Printing House for the Blind
1839 Frankfort Avenue
Louisville, KY 40206
USA
(502) 895-2405

The American Printing House for the Blind (APH) is a national organization for the production of literature and the manufacture of educational materials and devices for visually impaired persons. APH produces braille books, large-type textbooks, and educational recordings; manufactures special educational devices; modifies and develops computer-access equipment and software; maintains an educational research and development program; and maintains a reference-catalog service providing information about volunteer-produced textbooks in all media for visually impaired students and about other sources of educational materials.

Australian Institute of Cartographers
G.P.O. Box 1292
Canberra ACT 2601
Australia
06-288-6710

The Australian Institute of Cartographers promotes research and information dissemination relating to map production.

Australian National Council of and for the Blind
c/o P.O. Box 162
Kew, Victoria 3101
Australia
03-860-4444

The Australian National Council of and for the Blind provides a forum for the exchange of ideas; coordinates national activities such as seminars and conferences; acts as a link with international organizations; and collects and disseminates information on blindness.

Canadian National Institute for the Blind
1931 Bayview Avenue
Toronto, Ontario M4G 4C8
Canada
(416) 486-2636

The Canadian National Institute for the Blind (CNIB) fosters the integration of blind and visually impaired persons into the mainstream of Canadian life and promotes blindness prevention programs. It provides rehabilitation and public education services and produces tactile graphics and texts in braille, tape, and large-print formats.

Canadian Rehabilitation Council for the Disabled
45 Sheppard Avenue East, Suite 801
Willowdale, Ontario 2N 5W9
Canada
(416) 862-0340

The Canadian Rehabilitation Council for the Disabled acts as a national advocacy, coordinating, and resource center for organizations serving Canadians with disabilities.

Christoffel-Blindenmission
Nibelungenstrasse 124
D-6140 Bensheim 4
Germany
06251-1310

Christoffel-Blindenmission works in a wide variety of areas relating to blindness in more than 60 countries and emphasizes the prevention of blindness and the treatment of eye diseases. It provides substantial support to educational and rehabilitation services for blind persons.

Computer Center for the Visually Impaired
Baruch College
Box 515, 17 Lexington Avenue
New York, NY 10010
USA
(212) 447-3070

The Computer Center for the Visually Impaired provides information on and training for adaptive computer technology, offers classes and individual instruction in computer programs, manages a braille production service, and provides equipment evaluation consultations. Its Tactual Graphics Project has developed a computer-aided system to produce tactile graphics.

Deutsche Blindenstudienanstalt e.V.
Am Schlag 8
P.O. Box 1160,
D-3550 Marburg 1
Germany
06421-6060

Deutsche Blindenstudienanstalt manufactures and distributes devices for blind persons, including braille writing, braille printing, and embossing machines; computerized braille production systems; and tactile materials. It also provides consultative services for professionals and libraries serving blind and visually impaired persons.

Division for the Visually Handicapped
Council for Exceptional Children
1920 Association Drive
Reston, VA 22091
USA
(703) 620-3660

The Division for the Visually Handicapped of the Council for Exceptional Children (CEC) is a professional organization of teachers, school administrators, and others concerned with children who require special services. It publishes periodicals, books, and other materials on teaching the exceptional child.

Howe Press
Perkins School for the Blind
175 North Beacon Street
Watertown, MA 02172
USA
(617) 924-3434

The Howe Press manufactures and sells a wide range of materials and equipment, such as the Perkins Brailler, manual or electric; braille slates and styli; mathematical aids; braille games; braille-vision books for children; and braille paper.

Institute Nazareth et Louis Braille
1255 Beauregard
Longueuil, Quebec J4K 2M3
Canada
(514) 463-1710

The Institute Nazareth et Louis Braille provides free aids and devices to visually impaired persons, maintains a library for braille materials and Talking Books (3,000 titles), operates a residential school, undertakes research, and disseminates information regarding the treatment of blindness and visual impairment.

Library of Congress National Library Service for the Blind and Physically Handicapped
1291 Taylor Street, N.W.
Washington, DC 20542
USA
(202) 707-5100 or (800) 424-9100

The Library of Congress National Library Service (NLS) for the Blind and Physically Handicapped conducts a national program to distribute free reading materials in braille and on recorded disks and cassettes to blind and visually impaired persons who cannot utilize ordinary printed materials. In addition, it operates a reference service providing information on reading materials for disabled persons.

Nippon Lighthouse
Welfare Center for the Blind
2-14-34 Morigawati-Nishi-2
Higasi-osaka 577
Japan
06-784-4414

Nippon Lighthouse Welfare Center for the Blind maintains an information and cultural center for blind persons. It provides social adjustment and industrial vocational training and also operates a braille printing plant.

Royal Commonwealth Society for the Blind
Commonwealth House, Heath Road
Haywards Heath, Sussex RH16 3AZ
England
UK

The Royal Commonwealth Society for the Blind provides eye care services and education, training, employment, and follow-up services for blind people. It also provides funds for educational scholarships and equipment, employment placement, and self-help projects.

Royal National Institute for the Blind
224 Great Portland Street
London, W1N 6AA
England
UK
441-388-1266

The Royal National Institute for the Blind (RNIB) works to promote the welfare of all blind people in the United Kingdom. In addition, it maintains a library of Talking Books, conducts training courses and an educational advisory service, publishes materials in braille, and produces and sells equipment and products for blind and visually impaired persons.

Swedish Federation of the Visually Handicapped
S-122 33 Enskede
Sweden
08-39 -0245

The Swedish Federation of the Visually Handicapped (SRF) conducts research on issues related to blindness and visual impairment, maintains a library of materials in braille and cassette format, and develops and produces products for persons who are blind or visually impaired.

APPENDIX 3

Sources of Materials and Equipment

A great number of companies and organizations manufacture and sell materials used in the making of tactile graphics. The following is a representative list of suppliers from whom equipment can be ordered. Readers should note that the information given was current as of the writing of this publication; names, addresses, and telephone numbers are therefore subject to change. For example, as this book went to press, the name of RPH-SYN, the National Center for Educational Aids for the Blind, in Solna, Sweden, which is mentioned several times in the text, was changed to SIH Laromedel I Solna.

American Foundation for the Blind
15 West 16th Street
New York, NY 10011
USA
(212) 620-2000 or (800) 232-5463 (Hotline)

American Printing House for the Blind
1839 Frankfort Avenue
Louisville, KY 40206
USA
(502) 895-2405

American Renolit Corporation
135 Algonquin Parkway
Whippany, NJ 07981
USA
(201) 887-8390

American Thermoform Corporation
2311 Travers Avenue
City of Commerce, CA 90040
USA
(213) 723-9021

Bostik Aktiebolag
Emhart Fastening Systems Group
P.O. Box 903
S-251 09 Helsingborg
Sweden
42-14-4000

C.R. Clarke and Company
Bettws Industrial Park
Estate Foundry Road
Ammanford, Dyfed, SA18 2LS
Wales
UK

Deutsche Blindenstudienanstalt e.V.
Am Schlag 8
P.O. Box 1160
D-3550 Marburg 1
Germany
06421-6060

American representative:
Braille International
3142 S.E. Jay Street
Stuart, FL 34997
USA
(407) 286-8366

Emhart Consumer Group
4408 Pottsville Pike
P.O. Box 3716
Reading, PA 19605
USA

Esselte Dymo International
Esselte House
4 Buckingham Gate
London SW 1 E6JR
England
UK
077-828-9031

Graphic and Display Products
173-179 Tyburn Road
Birmingham, B24 8NQ
England
UK

Howe Press
Perkins School for the Blind
175 North Beacon Street
Watertown, MA 02172
USA
(617) 924-3434

Japan Braille Library
23-4 Takadanobaba 1-chome
Shinjuku-ku
Tokyo 169
Japan

Kissel and Wolf
GmbH, Postfach 1326
D-6908 Wiesloch
Germany

Low Vision International
Storgatan 30
S-352 31 Växjo
Sweden

Mark-Tex Corporation
7303 Monetary Drive
Orlando, FL 32809
USA

Maryland Computer Services
2010 Rock Spring Road
Forest Hill, MD 21050
USA

Matsumoto Kosan Company
2-14, Nishi Honmachi 1-chome
Nishi-ku , Osaka
Japan
American distributor:
J.P. Trading
300 Industrial Way
Brisbane, CA 94005
USA
(415) 468-0775

Mecanorma S.A.
14 Route de Houdan
78610 Le Perray-En-Yvelines
France

Mobility Aids
50 Springfield Road
Moseley
Birmingham B13 9NP
England
UK

Quantam Technology Pty Ltd.
5 South Street
Rydalmere N.S.W. 2116 Sydney
Australia

Renolit Norge A:S:
Postboks 198
1501 Moss
Norway

Royal National Institute for the Blind
224 Great Portland Street
London W1N 6AA
England
UK
441-388-1266

RPH-SYN (the National Center for Educational Aids for the Blind)
see SIH Laromedel I Solna

Senoplast Klepsch and Company
Postfach 3
A-5721 Peisendorf
Austria

SIH Laromedel I Solna (formerly RPH-SYN)
Tomtebodavägen 11
S-171 64 Solna
Sweden
08-736-0140

Smith Brothers Asbestos
17 Crossgate Drive
Industrial Estate, Nottingham
England
UK

Storm and Company
Algrafik Aps, Henriettevej 1-3
Odense
Denmark

Svenska Hoechst AB
Box 5415
402 29 Göteborg
Sweden
03-167-8500

TeleSensory
455 North Bernardo Avenue
P.O. Box 7455
Mountain View, CA 94039
USA
(415) 960-0920 or (800) 227-8418

3M Company
Minnesota Mining and Manufacturing
3M General Office
St. Paul, MN 55144
USA
(612) 733-1110

3M Europe S.A.
106 Boulevard De Lawoluwe
B-1200 Brussels
Belgium

Toppan Printing Company
5, 1-chome Taito
Taito-ku, Tokyo
Japan
03-3295-2411

Transatlantic Plastics
67 Fulham Road
London SW6
England
UK

Traylor Enterprises
830 N.E. Loop 410, Suite 505
San Antonio, TX 78209
USA
(512) 923-1481

Turner Whitehead Industries
1 Leathermarket Street
London SE1
England
UK

APPENDIX 4

Resources for Further Reference

Reference materials containing useful information on blindness and visual impairment and the needs of visually impaired persons, tactile graphics and their production, other materials for visually impaired readers, and related issues can be of invaluable assistance. The following listing of books and periodicals is a sampling of helpful materials.

BOOKS

Basic Cartography. By the International Cartographic Association. (Vol. 1, English version, 1984; Vol. 2, 1987). Available from Rudolph Muller, International Booksellers, P.O. Box 9016-1006 AA, Amsterdam, The Netherlands.

Directory of Services for Blind and Visually Impaired Persons in the United States, 23rd edition (1988). Published by the American Foundation for the Blind, 15 West 16th Street, New York, NY 10011, United States. A comprehensive listing of schools, agencies, organizations, and programs that provide a variety of direct and indirect services to blind and visually impaired persons and the professionals who work with them.

First Step to Tactual Graphics for Braille Writing. (Japanese language edition). Published by the Japan Braille Library, 23-4 Takadanobaba 1-chome, Shinjuku-ku, Tokyo 169, Japan.

Foundations of Orientation and Mobility. Richard L. Welsh & Bruce B. Blasch (Eds.). (1980). A basic and comprehensive overview of the origins, history, and present state of orientation and mobility training. Published by the American Foundation for the Blind, 15 West 16th Street, New York, NY 10011, USA.

General Report of the First European Symposium on Tactual Town Maps for the Blind. (1983). Minutes of an international symposium that established uniform symbols to be used in tactile maps. Participants included public and private blindness organizations, surveyors, and map publishers. Available from Dr. Jean-Paul Herbecq, President, La Ligue Braille, 63 Avenue des Dames Blanches, B-1150 Brussels, Belgium.

Guidelines for Mathematical Diagrams. (1983). Developed and published by the Braille Authority of North America. Distributed by the Braille Book Bank, National Braille Association, 422 Clinton Avenue South, Rochester, NY 14620, USA.

Handbook on Mobility Maps. G.A. James & J.D. Armstrong (Eds.). (Monograph No. 2, 1976).

Outlines the step-by-step techniques used in designing and producing tactile mobility maps, describes methods of teaching map-reading skills, and includes appendixes on materials, supplies, and reference materials. Available from Mobility Aids, 50 Springfield Road, Moseley, Birmingham B13 9NP, England, UK.

International Directory of Agencies for the Visually Disabled. By J.M. Gill. (1986). Contains information about the main organizations of and for visually impaired people in 135 countries, including the organization's name, address, telephone number, contact person, and summary of activities. Distributed by Customer Liaison Department, Royal National Institute for the Blind, 224 Great Portland Street, London W1N 6AA, England, UK.

International Directory of Libraries and Production Facilities for the Blind. By Frank Kurt Cylke & Peter Hanke. (1984). Distributed by Consumer Relations Section, National Library Service for the Blind and Physically Handicapped, 1291 Taylor Street, N.W., Washington, DC, 20542, USA.

International Directory of Tactile Map Collections. By Frank Kurt Cylke & Judith Dixon. (1985). Includes the names and addresses of organizations in 18 countries that have tactile map collections. Lists and describes each map in the collection and indicates which organizations lend or sell maps. Distributed by Consumer Relations Section, National Library Service for the Blind and Physically Handicapped, 1291 Taylor Street, N.W., Washington, DC 20542, USA.

International Guide to Aids and Services for the Deaf-Blind. By J.M. Gill. (1986). Covers available devices and aids for deaf-blind persons, aids for which plans are readily available, major sources of information, current nonmedical research on deaf-blindness, and services for deaf-blind persons. Distributed by Customer Liaison Department, Royal National Institute for the Blind, 224 Great Portland Street, London W1N 6AA, England, UK.

International Guide to Educational Aids and Materials for the Visually Disabled. By J.M. Gill. (1986). Includes details on aids for preschool and primary-school children, games and puzzles, and the teaching of braille and spelling, as well as materials on the utilization of low vision, rules and measures, geography, mathematics, science, embossed maps and diagrams, music, and sports. Distributed by Customer Liaison Department, Royal National Institute for the Blind, 224 Great Portland Street, London W1N 6AA, England, UK.

International List of Schools for Visually Handicapped Children. (1986). Published by the International Council for Education of the Visually Handicapped. Lists addresses and basic information for schools for visually impaired students, schools for deaf-blind students, and self-contained units for visually impaired students in regular schools. Available from W.A. Stein, Johann Sebastian Bach Strasse 9, D-6141 Einhausen, Germany.

International Register of Research on Visual Disability. By J.M. Gill. (1986). The first section of this register contains information about current nonmedical research on visual impairments, including the name of the principal investigator, address, and summary of current projects. The second section includes information about journals that publish articles on nonmedical research on visual disability. Distributed by Customer Liaison Department, Royal National Institute for the Blind, 224 Great Portland Street, London W1N 6AA, England, UK.

International Survey of Aids for the Partially Sighted. By J.M. Gill. (1986). In large print (16-point type). Covers electronic reading devices, magnification of visual-display units, and adaptive aids and devices for money handling, handwriting, typing and reading. Distributed by Customer Liaison Department, Royal National Institute for the Blind, 224 Great Portland Street, London, W1N 6AA, England, UK.

International Survey of Aids for the Visually Disabled. By J.M. Gill. (1986). Contains information on over 1,000 adaptive devices that are available commercially, including the manufacturer's address, a brief description

of the device, a photograph of the device, and the price. Distributed by Customer Liaison Department, Royal National Institute for the Blind, 224 Great Portland Street, London, W1N 6AA, England, UK.

Maps and Graphics for Blind and Visually Handicapped Individuals: A Bibliography. By Judith M. Dixon. (1984). Provides listings of materials of interest to tactile map producers and researchers, including annotations for some items. Distributed by Consumer Relations Section, National Library Service for the Blind and Physically Handicapped, 1291 Taylor Street, N.W., Washington, DC 20542, USA.

National Specifications for Tactual and Low Vision Town Maps. (1985). Published by the National Mapping Council of Australia. Available from Division of National Mapping, Australia Department of Resources and Energy, P.O. Box 31, Belconnen, ACT 2616, Australia.

Proceedings of the First International Symposium on Maps and Graphics for the Visually Handicapped. Joseph W. Wiedel (Ed.). (1983). Published by the Association of American Geographers, 1710 16th Street, N.W., Washington, DC 20009, USA.

Symbols for Tactual and Low Vision Town Maps. (1986). Published by the National Mapping Council of Australia. Available from Division of National Mapping, Australia Department of Resources and Energy, P.O. Box 31, Belconnen, ACT 2616, Australia.

World Braille Usage. By Judith M. Dixon (1987). Contains braille codes for mathematical, scientific, literary, computer-related, and musical materials, gathered from about 80 countries. Available from Consumer Relations Section, National Library Service for the Blind and Physically Handicapped, 1291 Taylor Street, N.W., Washington, DC 20542, USA.

PERIODICALS

Aids and Appliances Review. Robert McGillivray (Ed.). (No. 14, Fall 1984). Special issue devoted to tactile graphics research and resources. Discusses hand-made, machine-produced and computer-generated materials. Also includes sections on research needs, applications and training, and large production centers. Available from the Carroll Center for the Blind, 770 Centre Street, Newton, MA 02158, USA.

Braille Research Newsletter. Published by the Research Unit for the Blind, Institute for Bioengineering, Brunel University, Uxbridge, Middlesex UB8 3PH, England, UK.

Horus, Marburger Beitrage zur Integration Sehgeschadigter. Published quarterly in German, with abstracts in English and French, by Deutsche Blindenstudienanstalt e.V. and Verein der Blinden Geistesarbeiter Deutschlands e.V., Am Schlag 8, D-3550 Marburg/Lahn, Germany.

Journal of Visual Impairment & Blindness. An interdisciplinary, peer-reviewed journal for practitioners, researchers, and other professionals working with blind and visually impaired persons. Published monthly by the American Foundation for the Blind, 15 West 16th Street, New York, NY 10011, USA.

New Outlook for the Blind. Maps: Designing them, making them, reading them. (Vol. 66, No. 8, October 1972). Formerly published by the American Foundation for the Blind, 15 West 16th Street, New York, NY 10011, USA; in 1976, the title of this journal was changed to the *Journal of Visual Impairment & Blindness.*

Review of the European Blind. Published quarterly in English, French, German, and Russian by the Secretariat, European Regional Committee, World Council for the Welfare of the Blind, c/o Dr. H. Pielasch, Poststrasse 4-5, DDR 102 Berlin, Germany.

Tactual Mapping Newsletter. Available by subscription from Chairman, Tactual Mapping Division, Australian Institute of Cartographers, G.P.O. Box 1292, Canberra ACT 2601, Australia.

Glossary and Illustrations

Glossary

This glossary, which contains a sampling of common terms used in relation to tactile graphics, has been compiled with the help of many references. The following have been especially useful: *Webster's Ninth New Collegiate Dictionary* (Springfield, Massachusetts: Merriam-Webster, 1983), *The New Collins Concise English Dictionary* (Glasgow: William Collins Sons & Company, 1982), *Encyclopaedia Britannica* (London: William Benton, 1963), *Media Familjelexikon* (Stockholm: Albert Bonniers Förlag, 1981), *Svensk-Englisk Ordbok* (Stockholm: Natur o. Kultur, 1975), and *The Designer's Handbook* (London: Alastair Campbell, Macdonald & Company, 1983).

Acute angle. An angle of less than 90°.

Adhesive paste. A commercial composition used to fasten posters and pictures to walls and woodwork. It has the consistency of caulking material that is used to fill cracks, such as those in window frames and doors. The paste is pliable and dry and leaves no marks when removed. See **Blu-Tack.**

Answer card. A type of reader-participation display in which dots representing certain answers can be pushed down in response to questions (see "Answer Cards and Pop Sheets," Chapter 2).

Answer line. A line used in a workbook or questionnaire, on which the reader is asked to write an answer to a question. For blind and visually impaired people, blank spaces are usually substituted for answer lines in relief material. The reader is often asked to answer the questions on a separate sheet of paper.

Apex. The pointed end or tip of something; the highest point; the vertex.

Arabic numbers. The digital symbols 1, 2, 3, 4, 5, 6, 7, 8, 9, and 0, which are often referred to in this book as inkprint numbers.

Architectural plan. A line drawing showing the ground or floor plan of a building.

Areal symbol. A textured symbol covering a particular extent of space or surface in a picture, map, or diagram. Symbols vary greatly and are determined by the shape, size, and pattern of the texture and the information they represent (see "Areal Symbols," Chapter 6.)

Arrowhead. The head of an arrow (see "Arrows," Chapter 4).

Asterisk. A symbol [*] usually used to indicate a footnote to the text. In braille, the asterisk,

represented by dots 3-5, 3-5, is used to indicate all marks of reference.

Axis. A straight line, usually in a graph, along which distances are measured or to which positions are referred. In graphs, one line or axis is usually perpendicular to the other.

Background. In an illustration, the part of the image that appears farthest from the viewer or on which the main subject is superimposed. In a relief display, it is the material (paper, cardboard, embroidery canvas, or wood) on which the components of the display are fastened or mounted.

Bar graph. A graph consisting of vertical or horizontal bars whose lengths are proportional to the segments of data being depicted or compared.

Baseline (also called *reference line*). The line in a relief display on which an object or person is placed. This line keeps the objects from becoming free-floating forms in the display and gives the reader an orientation point to which he or she can relate. See **Point of reference.**

Basic paper size. A standard size for a particular type of paper (see Appendix 1). The size of standard braillewriter paper may vary from country to country.

Bas-relief. See **Low relief.**

Binder. A medium of some liquidity that forms paint when mixed with a powdered pigment. Also, a cover in which papers are gathered and secured, as in a loose-leaf notebook.

Blank space. When writing braille, an empty space the size of one braille cell.

Blindness. The absence of sight. The term "legal blindness" is used to refer to conditions ranging from total blindness to partially useful vision. In the United States, legal blindness is visual acuity in the better eye that is 20/200 or poorer even with the best possible correction or a visual field constricted to a diameter of 20 degrees or less. A person is adventitiously blind if he or she became blind from an accident or illness. A person is congenitally blind if he or she has been blind from birth.

Blu-Tack. The commercial name for a reusable sealant, a nondrying sticking agent used to affix two items temporarily. Available in Scandinavia under the name of Häftmassa from Bostik Aktiebolag, Emhart Fastening Systems Group, and in the United States, from Emhart Consumer Group (see "Sources of Materials and Equipment," Appendix 3).

Bracket. A symbol [{] often used to join several items together or to indicate that they are related in some way.

Braille. A tactile reading and writing system for blind persons, invented in France in 1829 by Louis Braille. It is based on a rectangular figure of six raised dots, two rows of three dots each. Each letter of the alphabet, number, and symbol is a combination of one to six dots (see "Braille," Chapter 4). Grade 1 braille does not use any contractions. Grade 2 is contracted braille. A contraction is a short version of the word in which one symbol is substituted for several letters. For example, "r(ea)d(er)" is written with four braille characters instead of six. The letters between the parentheses become one symbol.

Braille paper. A type of firm paper that retains an embossed impression. The standard size of braille paper may vary slightly from country to country, depending on the type of braillewriter most commonly used in that country. The size 11 1/2 in. by 14 in. (29 cm by 35.5 cm) is used in many countries.

Braille transcriber. A person who translates or transcribes printed words into a raised-dot braille text with a slate and stylus, a braillewriter, or a computer attached to a braille printer.

Braillewriter. A braille typewriter consisting of six keys corresponding to the six dots of the braille system. Text from the machine is printed in tactile raised dots.

Brailon. A commercial name for a thin, heat-sensitive plastic sheet that is used in a vacuum-forming machine. It is used for producing multiple copies from an original relief display.

Buildup (also called *paper buildup*). A technique in which several layers of paper or cardboard forms are glued to a paper or cardboard background. Also, the resulting display.

CAD. Computer-aided design; the use of computer output information in graphic form, such as a picture, diagram, map, or printed characters.

Carbon paper. A thin sheet of paper coated on one side with a dark waxy pigment, often containing carbon. Pressure on the back of this paper causes the color to be transferred to the surface on which it has been placed.

Cardburr. The commercial name of a self-adhesive material that can be used in displays with movable parts.

Caricature. A drawing of a person or object showing distortion by the exaggeration of parts or characteristics. It is difficult for most blind readers to understand an image made with this technique.

Cartesian graph. A graph consisting of two axes that bisect each other at right angles. The axes are graduated numerically in both directions from their point of intersection (see "Cartesian Graphs," Chapter 8).

Cassette. A plastic cartridge containing magnetic tape on two small reels that records sound and plays it back; used for recording audio descriptions that accompany tactile graphic displays.

Chart (also called *diagram* or *graph*). A display giving graphic, tabular, or diagrammatical information.

Chinese ink. See **India ink.**

Choice point. A place along a route where a blind traveler must decide whether to go left, right, or straight ahead (see "Topological Maps and Choice Points," Chapter 6).

Circle diagram. A diagram using parts of a circle or a circle form to indicate the relationship between two or more elements or quantities.

Circumference. The outside boundary of a figure or object, especially a circle.

Closed-circuit television (CCTV). A machine in which printed material is enlarged electronically and is displayed on a television screen.

Clutter. In connection with tangible graphic displays, a condition marked by such elements as irrelevant information, too many symbols within a particular area, the wrong spacing between symbols, too many different types of symbols, and too many similar symbols, which make a display crowded and confusing to the reader.

Coded symbols. Braille characters or simple forms, often geometric in shape, which are substituted for the more complicated forms of a printed display when it is not necessary to maintain their original shapes and textures (see "Coded Symbols," Chapter 8).

Collage. An art form in which the display is made up of pieces of paper, cloth, wood, photographs, and the like that are pasted onto a background. The composition is often based on an abstract emotion or idea rather than a pictorial illustration.

Compass. An instrument having a magnetized needle that points to magnetic north, used for determining direction. Also, an instrument consisting of two arms joined at one end, used for drawing circles and measuring distances.

Computer graphics. The use of computers to output information in graphic form, such as pictures, maps, and diagrams.

Concave. Having the shape of a section of the interior of a sphere; curving inward.

Con-Tact paper. The commercial name of paper that has been coated with an adhesive on one side. It will stick to another material without being glued in place.

Contour lines. Lines describing the silhouette and volume of a form.

Contour paste. A plastic substance used in painting glass to make a relief line between the painted surfaces. It gives the impression of lead in a stained-glass window. It can be used for making relief lines on a plastic or paper display.

Contrast. To exhibit noticeable differences when compared side by side with another object, form, or material.

Convex. Curved or rounded, as the exterior of a spherical or circular form; the opposite of concave.

Copying machine. See **Duplicating machine.**

Copyright. Protection under law for the originator of text or illustrations, intended to prevent the reproduction of material without the owner's permission. To obtain permission to

use any copyrighted materials, it is important to check with authors, publishers, or artists before changing inkprint material into braille books with relief displays.

Cross reference. An instruction to the reader to refer to another part of the text for related information.

Cube. A solid form having six plane square faces, in which the angle between two adjacent sides is a right angle (see "Geometry," Chapter 8).

Curves. Templates made of plastic or metal that aid the designer in drawing a smooth curve. A French curve combines several curves in one shape.

Dash. A symbol [—] often used in a series to indicate a boundary line or pedestrian path.

Data. A series of observations, measurements, or facts; information.

Data bank. Information collected and stored in a computer.

Density. The degree to which something is filled or occupied; a measure of the compactness of a substance.

Diagram. A line drawing, mechanical plan, or outline, as distinguished from a perspective drawing; a rough projection, map, chart, or graph. In this book, the words "diagram" and "display" are sometimes used interchangeably.

Directional or tactile arrow. An arrow that indicates direction and is made with a special instrument that imprints a sawtooth pattern when it is rolled across a surface.

Directly embossed. The technique in which inkprint material is transcribed into raised forms that preserve the shapes and texture contrasts of all elements in the original layout. Opposed to "embossed in coded symbols," in which the original material is transcribed into raised symbols differing in form from the original inkprint material but systematically related to the original material.

Display. The arrangement of lines and forms on a printed or relief page; an illustration or layout.

Divider. A type of compass with two pointed arms, used for measuring lines and spaces or dividing them.

Dot. The symbol [•], one of six components of a braille cell. Different sizes and quantities of dots are often used in relief textures.

Double-backed tape (also called *double-sided tape*). A tape or film that is coated with an adhesive substance on both sides of its surface. Two materials will stick together if the tape is mounted between them.

Drafting paper. A semitransparent paper used in making drawings.

Drawing board. A board or table on which drawings can be made. For blind people, a small rubber-coated or plastic sheet over which plastic film can be fastened. Drawings are made by pressing a ballpoint pen or stylus against the film. The pressure causes a welt to rise in the film, and a relief drawing can be felt as a result (see "Raised-Line Drawing Boards," Chapter 2).

Dry-transfer lettering and textures. See **Instant dry-transfer lettering and textures.**

Duplicating machine (also called *duplicator, copying machine,* or *photocopier.*) An apparatus for making duplicates of sheets of paper containing written or printed matter or drawings.

Dymo tape. The commercial name for a plastic tape on which a relief braille symbol or inkprint letter or number can be embossed by using a tape slate and stylus or a hand-operated tape labeler or by attaching a tape holder to a braillewriter.

Edit. To revise and prepare a manuscript or pictures, maps, diagrams, and charts for publication. In regard to tactile graphics, to make all necessary changes in original printed matter so the material can be read and understood by blind persons or those with low vision when it is produced in a tangible graphic display.

Electroforming. A method for accurately reproducing the forms of materials on a sheet of metal, often used to create metal tactile displays for public places.

Elevation. A raised area; height. Also, a drawing showing the vertical projection of an object, building, bridge, and so forth. The opposite of a horizontal projection.

Ellipse. An oval shape (such as an egg) corresponding to an oblique view of a circular plane.

Emboss. To cover or adorn a surface with raised figures and designs.

Embossed-line drawings (also called *raised-line drawings*). Relief illustrations or tactile graphic displays made for blind people. Embossed-line drawings can also be made by blind people on metal foil or on a raised-line drawing board.

Engrave. To inscribe a design onto a block, plate, or other printing surface by carving, etching, or other processes.

Etching. Design on metal or glass made by lines eaten into the metal by a corrosive agent.

Euro-Town-Kit. See **Nottingham Map Making Kit.**

Exploded view. A drawing of an object showing its component parts separately, yet arranged in such an order that the reader will understand the relationship of these individual parts to each other and to the object as a whole. One type of a step-by-step display.

Facing page. A page in a braille book that is bound so that braille text or a relief display faces it as brailled text on the opposite page. In books brailled on one side of the page, the usual procedure for nonfacing pages is to have the brailled pages follow in succession.

Figure number. The reference number given to a printed illustration. In a tactile graphic display, this number should appear above the illustration and to the left of it, irrespective of where the number is located on the printed page. The titles of illustrations should be placed in the same location.

Finger index. See **Thumb index.**

Flannel-board diagram. A diagram that is made up of movable items placed on a flannel-covered board.

Flexible curve (sometimes called a *snake*). A thick, pliable metal wire covered with plastic, average length 18 in. (46 cm). It can be formed to any desired curve and will remain in that position until changed. It is used as a drawing aid with a raised-line drawing board.

Flocking. Tiny tufts of wool applied to fabrics, paper, and other materials to produce a raised pattern. The fibers are usually blown over an adhesive ink base.

Foldout page. A paper or plastic extension of a braille page or a relief display. It increases the information area in width or length and is folded over or under the display when not in use.

Foreshorten. To represent a line, form, or object as shorter than its actual length to give the illusion of recession or projection. The object does not appear in its true proportions but is distorted, or foreshortened. This technique should not be used in materials for people who are blind or visually impaired.

Form. The shape of an object, as distinct from its color or texture. In this book, the terms "form" and "shape" are used interchangeably.

Free form. Having an irregular shape; not contained in an orderly fashion.

Freehand drawing stylus. See **Tongs.**

Graph (also called *chart*). A drawing depicting the relationship between certain sets of numbers or quantities by means of a series of dots and lines plotted with reference to a set of axes.

Graphic. Any art that expresses ideas by means of lines, marks, or characters impressed on a surface.

Graphic design. Any of the fine or applied visual arts that are based on drawing or the use of line. Also, a design based on impressions printed on flat surfaces, such as illustrations, prints, or photographs.

Grid. A network of horizontal and vertical lines superimposed over a map or building plan for locating points.

Haptic. Relating to the sense of touch.

Hardware. Manufactured articles of metal, such as utensils or tools. Also, the physical equipment used in a computer system, such as the central processing unit and peripheral devices. Opposed to **Software.**

Hatch. To mark a drawing with fine, closely spaced lines that are parallel or crossed. The pattern made is called "hatching"; it is often used to give the effect of shading.

High relief. A relief in which figures or shapes project very distinctly from the background. Opposed to **Low relief.**

Histogram. A graph of a frequency distribution in the form of a series of rectangles whose width is in proportion to the class interval under consideration and whose height is the

associated frequency (see "Histograms or Box Graphs," Chapter 8).

Index marks. See **Scale marks.**

India ink (also called *Chinese ink*). A black pigment, composed of a mixture of lampblack or burnt cork, gelatin, and water. Originally made in India, China, and Japan, it was molded into sticks or cakes. A liquid ink was made from this pigment.

Infrared heater. A heater used in offset printing or in the swelling process for microcapsule paper (see "Microcapsule Paper," Chapter 2).

Inkprint. Letters and other text that are printed for sighted readers.

Instant dry-transfer lettering and textures. Inkprint lettering, point symbols, lines, textures, and braille characters that are printed in black on the back of a thin sheet or strip of transparent plastic film. The printed image is transferred to the desired background by rubbing the plastic film with a pencil or a wooden, nylon, or metal stick. Letraset and Mecanorma are two well-known commercial brands of dry-transfer products.

Integrated settings. School classes or other programs in which individuals or groups of various abilities, characteristics, and cultural, economic, racial, and physical backgrounds receive instruction together, such as classes that both blind and sighted students attend. Opposed to **Segregated settings.**

Intensity. The degree or amount of strength, force, or quantity of objects, symbols, or text in a display.

ISBN. The International Standard Book Number, a reference number given to every published work, based on a system that identifies the area of origin, publisher, title, and check control encoded in a ten-digit number. Each new edition of a book is given a new ISBN. It is important to check ISBNs when textbooks and graphic displays are ordered for transcription into braille or relief displays. A few numbers can mean the difference between a new and an old edition of the same title.

Jumbo braille. Oversized relief dots used in forming a braille cell. This type of braille is often used for young or beginning readers or for people who have difficulty reading standard braille. Slates, braillewriters, and single-dot tongs are available in this size (see "Braille," Chapter 4).

Key (also called *legend*). A list of explanations of the symbols, abbreviations, and codes used in connection with a picture, diagram, map, or graph. In an alphabetical key, words or abbreviations are arranged in alphabetical order. In a numerical key, numbers are arranged in numerical order, each number accompanied by a definition. In a symbol key, small portions of point, line, and areal symbols are duplicated, explaining their purpose in a display. The symbol key should always be placed first in the key list (see "Key or Legend," Chapters 4 and 6).

Large-print books (also called *large-type books*). Books made for readers with low vision, in which the printed text is larger than the average book text. Pictures, maps, and graphs in these books are also enlarged and often simplified, and frequently the outlines of figures and objects have been retouched.

Layout. The arrangement of written material, photographs, or other artwork on a page. Also, a drawing showing the relative disposition of parts.

Lead line. A fine line that connects a label with the object to which it relates. It is used when the label is more than 1 in. (2.5 cm) from the object.

Legend. See **Key.**

Letraset. A commercial name for instant dry-transfer lettering or textures.

Light table (also called *light box* or *light board*). An apparatus with a smooth, transparent surface that is illuminated beneath the work area. It is especially useful when drawing maps, pictures, and graphs with several overlays.

Linear. Pertaining to or composed of lines.

Line graph. A diagram in which a relationship between two or more elements is indicated by means of a system of dots, curves, or lines.

Line symbol. A symbol made up of lines that indicates location or direction (see "Line Symbols," Chapter 6).

Loose-leaf binder (also called *ring binder*). A folder in which sheets of paper are held in place by metal rings that can be opened

and closed. This type of binding is especially useful for relief maps and pictures because the material can be easily replaced or removed.

Lowercase. See **Uppercase.**

Low relief (also called *bas-relief*). A very shallow relief in which the figures or shapes project only slightly from the background. Opposed to **High relief**, which is obtained in a buildup master or display. The relief is made by gluing one layer of braille paper or sandpaper to a background sheet of braille paper. Often used with a braillewriter for answering questions and solving arithmetic problems.

Low vision. Vision loss severe enough to interfere with the performance of everyday tasks but allowing some useful visual discrimination. In this book, it refers to vision that a person is able to use if the text or object is magnified.

Magnetic-board diagram. A display made up of movable items that are backed with magnetic tape and placed on a metal background.

Magnetic tape. A long, narrow plastic strip coated with iron oxide or chrome dioxide, used to record sound and for making Talking Books and audio cassettes or to store information in computers. Also, stripping consisting of a magnetic surface on one side and an adhesive surface on the other. When the tape is mounted on the back of various objects, the objects are attracted (magnetized) to a metal surface. Especially useful for movable parts of a relief mobility map or display. This material is available in various sizes of sheets, which can be cut with a scissors or knife to several widths.

Mask. To cover part of a display that should not be reproduced in a photograph or a copy-machine reproduction. The mask can be of paper, paint, or masking tape.

Masking tape. A paper tape used by architects, graphic designers, and house painters to cover particular areas that should not be painted.

Master. An original display from which duplicate copies can be made. Also, the plate containing the image for offset printing, for microcapsule paper displays, or for buildup displays for reproduction in a vacuum-forming machine.

Matrix. A mold or casting that gives form, origin, or foundation to something enclosed or embedded in it. Also, a plate of cardboard, metal, or wood from which plastic copies can be mass-produced in a vacuum-forming machine. In many instances, the terms "master" and "matrix" are interchangeable.

Mecanorma. A commercial name for instant dry-transfer lettering and textures.

Medium. The material or technique in which a work of art is executed; also, a means of spreading information, such as books, newspapers, radio, and television; an information source.

Microbraille. Minibraille or braille characters that are smaller than standard braille. Used mainly for taking notes produced by a slate and stylus. Useful on relief maps and charts where usable space is at a premium.

Microcapsule paper. A standard white or colored paper that has been coated with millions of microscopic plastic capsules called microcapsules. The capsules expand when subjected to heat.

Mobility map. A map that contains information on a limited local area, created to make it easier for persons to travel independently through the particular area (see "Mobility Maps," Chapter 6).

Moon script. A system of embossed characters consisting of simplified letters of the inkprint alphabet (see "Moon Script," Chapter 4).

Motoric. Relating to or concerned with muscular movement caused by impulses from the brain.

Mount. To affix, temporarily or permanently, one object, form, or material on another, often with glue or double-backed tape.

Negative shape. A shape that is cut into the surface of a material; an incised or intaglio design. Opposed to **Positive shape**, which is raised above the background material in a relief pattern. Negative and positive shapes are also referred to as "male" and "female" shapes when casting molds are discussed.

Nonfigurative picture. A tactile display made up of abstract or nonrealistic shapes that are used to represent other objects.

North line. The line used across the top of some map sheets to indicate the physical direction north (see "North," Chapter 6).

Nottingham Map Making Kit. A commercial kit for making relief maps, replaced by the Euro-Town-Kit (see Chapters 2 and 6).

Number line. A line marked with divisions that correspond to numbers progressing in a positive or negative direction from zero, often used to teach relationships among numbers.

Nyloprint. Photoengraving of metal or nylon plates, sometimes used for producing printing plates and relief materials for visually impaired persons.

Obtuse angle. An angle of between 90° and 180°.

One-of-a-kind display. A picture, map, diagram, or graph that is not meant to be made in more than one copy. Examples include a tactile-experience picture made with materials that are not heat resistant, a display made with movable parts, a cork map with different materials tacked to its surface, and flannel- and magnetic-board displays.

Optacon (Optical to Tactile Converter). A compact, portable reading aid for blind persons that converts a regular inkprint text into a vibrating tactile form. The blind reader moves a miniature camera across a line of print with one hand. The index finger of the other hand is placed on the Optacon's tactile array surface, an area approximately 1 in. by 1.5 in. (2.5 cm by 4 cm). As the camera is moved across a letter, the image is simultaneously reproduced on the tactile array surface by miniature vibrating rods.

Orientation. The adjustment or alignment of oneself within one's surroundings by becoming aware of the spatial relations between one's present position and significant places and objects in the environment.

Original. Any material or display that has been made for a specific purpose; the first form of a display from which other displays or copies can be reproduced.

Overlay. A sheet that is placed on top of a map, graph, or picture and augments the information on the original display. Opposed to **Underlay,** which is placed under the original display for the same purpose.

Oversized. Of text or graphic material, enlarged to fulfil the requirements of a reader with low vision.

Pantograph. An instrument consisting of pivoted arms for copying drawings, maps, or diagrams. It can enlarge or reduce the size of the displays (see "Enlargements and Reductions," Chapter 7).

Paper buildup. See **Buildup.**

Papier-mâché. A tough material made from paper pulp containing a mixture of sizing, paste, oil, and resin or from sheets of paper glued and pressed together.

Parallelogram. A four-sided figure whose opposite sides are parallel and equal.

Pattern. An arrangement of repeated or corresponding parts; a decorative design. Also, a plan or diagram used as a guide in making something.

Pattern discrimination. The ability to recognize or understand the difference among patterns used in the same display.

Perpendicular. Being at right angles to the plane of the horizon; upright or vertical. Also, a line at right angles to another line or to a plane.

Perspective. The art of conveying the impression of depth and distance. Also, the representation of scenes as they appear to the human eye: figures and objects in the distance appear much smaller than do figures and objects in the foreground. Linear perspective is the method of producing an appearance of distance by means of converging lines.

Photocopier. See **Duplicating machine.**

Pictograph. A diagram in which picture forms represent statistical information (see "Pictographs," Chapter 8).

Pinking shears. Shears or scissors with serrated blades for scalloping the edge of fabric. Also used for cutting zigzag patterns in paper, thin plastic, or metal foil.

Plane. Any flat or level surface of two dimensions, having length and breadth but no depth.

Plaster-of-paris. Calcined gypsum. Mixed with water, it sets readily and is useful in making molds, casts, and relief areas on displays. The dried plaster can be carved, filed, formed

with sandpaper, or painted. It can be used in a vacuum-forming machine.

Ply. A strand, turn, or twist of rope, yarn, string, or thread. Used in a combination of a certain number of folds, twists, or strands to create, for instance, three-ply thread.

Point of reference (also called *reference point*). A point from which a person can relate the experience or the objects and forms encountered on a two- or three-dimensional plane to his or her own knowledge and understanding. In graphics, an item to which all other items in a display are related. In this book, the point of reference is often referred to as the "reference line," and it is the line that keeps objects and forms from appearing to float free within the display. It gives the reader a line of departure from which he or she can discern the relationship of the objects in the display.

Points of the compass. Thirty-two equidistant directions or division points marked on a mariner's compass to indicate direction. Also, north, south, east, and west.

Point symbol. Symbolic figure used in tangible graphic displays to designate specific locations of objects (see "Point Symbols," Chapter 6).

Polygon. A closed plane figure consisting of several angles and a similar number of straight sides (see "Geometry," Chapter 8).

Polyhedron. A solid formed by plane faces, consisting of four or more faces (all polygons), pairs of which must meet along an edge (see "Geometry," Chapter 8).

Pop sheets. Sheets of raised dots in rows of various lengths and widths. A reader can answer multiple-choice questions, solve addition and subtraction problems, and form braille letters and numbers by pressing down the dots in a decided pattern (see "Answer Cards and Pop Sheets," Chapter 2).

Positive shape. See **Negative shape.**

Primary colors. The pure colors (red, yellow, and blue) from which all other colors can be mixed.

Print books. Books that are printed for sighted readers.

Prism. A solid whose bases or ends are any similar, equal, and parallel plane figures, and whose lateral faces are parallelograms (see "Geometry," Chapter 8).

Projection. The representation of a line, figure, or solid on a given plane as it would be seen from a particular direction.

Protractor. An instrument for measuring or drawing angles on paper; usually a flat, semicircular form graduated in degrees.

Putty. A stiff paste made of whiting and linseed oil that is used to fill holes or cracks in wood surfaces. Excellent for lengthening the life of braille characters and embossed-figure displays that are read frequently. Putty should be spread thinly over the back of a relief paper display.

Puzzle technique. A technique used to create displays with movable parts that are designed with separate forms that fit into indented areas on a page.

Pyramid. A solid structure with a square, triangular, or polygon base and triangular sides that meet at a common vertex (see "Geometry," Chapter 8).

Raised-line drawing (also called *embossed-line drawing*). A drawing made with relief lines; a relief display produced on metal foil; or an embossed drawing. Also, a drawing produced on a raised-line drawing board.

Raised-line drawing board. A special drawing board essentially consisting of a thin rubber sheet fastened to a firm backing and covered with a plastic sheet or muff. See also **Drawing board**.

Reading-direction arrow. An arrow placed in the upper right-hand corner of some displays to indicate the position in which the display is to be held while being read.

Reference line. See **Baseline, Point of reference.**

Relief. Technique in which forms and figures project from a surrounding plane surface. Also, the projecting forms and figures.

Retouch. To modify or improve.

Reusable adhesive. See **Adhesive paste, Blu-Tack.**

Right angle. An angle whose sides are perpendicular to each other; an angle of 90°.

Ring binder. See **Loose-leaf binder.**

Sans serif. A style of typeface in which the characters have no serifs. Opposed to **Serif.**

Scale. The ratio between the actual size of something and that of a representation of it, as illustrated by a picture, map, or technical drawing (see "Scale," Chapters 4 and 6).

Scale marks (also called *index marks* or *tick marks*). Marks along, above, or below a line, that divide it into regular intervals. They are found in graphs and diagrams (see "Grids and Guidelines," Chapter 8).

Scalpel. A surgical knife with a short thin blade.

Scan. To examine or search systematically. The blind reader will scan relief material with both hands moving over the entire surface of the display. Both hands are usually placed side by side and are moved from top to bottom and from left to right of the display.

Schematic. Of or relating to a diagram, plan, or schema, such as an analytical diagram of an electrical circuit.

Screen printing. A method in which paint or ink is forced through a silk or metal screen onto background material (see "Silk Screening" and "Screen Drawings," Chapter 2).

Segregated settings. School classes or other programs in which individuals or groups of various abilities or characteristics receive instruction separately or apart from each other. Opposed to **Integrated settings.**

Self-adhesive instant display. A display in which movable objects and the background used with them are both made of self-adhesive material, such as Velcro.

Sequin. A small piece of shiny metal foil or plastic, round and flat, used to decorate clothing. Can be used as a point symbol in a relief display.

Serif. Small line decorating a main stroke in a character of type. Also, the style of typeface in which such lines are part of the letters. Opposed to **Sans serif.**

Sewing-machine diagram. A relief picture or map made on paper, metal foil, or other material by using a sewing machine.

Shellac. A commercial preparation of a yellowish resin secreted by the lac insect. It is used in varnishes and polishes to saturate an area and give it a protective surface.

Silhouette. An outline drawing of an object, often cut out of paper or cardboard, that has been filled in with a uniform color, usually black.

Silk screening. A method of printing in which color is applied to a background by being forced through silk or other fine material and a stencil.

Slate and stylus. Tools for writing braille. The slate is a folding metal or plastic frame that is perforated on one side to allow the embossing of braille characters on a piece of paper, metal foil, or thin plastic using a stylus. A stylus is a pointed tool for engraving or embossing (see "Braille," Chapter 4).

Snap fastener. A round, flat, metal fastener consisting of two parts. One part has a projecting knob that snaps into a hole in the second part. Used mainly for fastening clothes. The knob part can be used as a point symbol in relief maps.

Software. The processing and operating package used to interface with a computer. Opposed to **Hardware.**

Sphere. A three-dimensional figure; a round, solid form such as a globe, a ball, or an orb.

Spray mount. An adhesive that is sprayed onto a surface. The glue is finely dispersed from a metal container by a propellant under pressure. There are two types of adhesives, temporary and permanent.

Spur wheel (also called *tracing wheel*). A tool consisting of a handle and a small serrated or notched wheel. A line of embossed dots can be formed on the reverse side of a sheet of braille paper or metal foil by rolling a spur wheel across the surface of the material (see "Embossed Paper Displays," Chapter 2).

Statistics. The collection, evaluation, interpretation, and presentation of masses of numerical information. Also, the information itself.

Stencil (also called *template*). A device for applying a design and characters to a surface, consisting of a thin sheet of plastic, metal, or paper, in which the design or characters have been cut so that ink or paint can be applied through the incisions onto the surface below.

Step-by-step technique. A display presentation in several steps, in which an object may be shown as a whole and then broken down

into its individual components; the different components may be shown separately and then added together to make the complete object; or the change an object can go through or an enlargement of particular areas of importance within the diagram may be shown.

String technique. The use of string or thread to make relief lines in a tactile display (see "Paper Buildup Displays Using Additional Materials," Chapter 2).

Stylus. See **Slate and stylus**.

Styrofoam. The commercial name of a white, porous material that is sold in blocks or in sheets of various thicknesses and can be cut or painted for use in tactile displays.

Swell paper. A commercial name for microcapsule paper, based on its capacity to swell when heated (see "Microcapsule Paper," Chapter 2).

Symbol. Something that represents or stands for something else and identifies an object, process, or activity. A letter, number, figure, concept, or sign used in mathematics, map making, science, and so forth (see "Symbols: General Information," Chapter 6).

Symmetrical. Having harmonious proportions or a correspondence in shape and size of parts; well balanced. In mathematics, an exact correspondence in position or form about a given point, line, or plane.

Tactile (also, *tactual*). Of, relating to, affecting, or having the sense of touch.

Tactile-experience picture. A tactile display made of materials that are as close as possible in feel to the surfaces of the objects they depict. They are used to familiarize blind readers with materials and shapes (see "Tactile-Experience Pictures," Chapter 2).

Tactile graphics (also called *tangible graphics*). Informational displays such as maps, charts, graphs, and illustrations that are made in relief to be touched.

Talking Books. Books recorded on audiotapes.

Template. See **Stencil.**

Tetrahedron. A polyhedron with four faces. A regular tetrahedron has faces that are equilateral triangles (see "Geometry," Chapter 8).

Thematic maps (also called *theme maps*). Maps that present qualitative or quantitative topical information on such subjects as population, industrial potential, and climate. Used to display the occurrence, quantity, pattern, and structure of the data and their geographic location.

Thermocopy. A plastic copy of a master, produced through heating in a vacuum-forming machine (see "The Vacuum-Forming Method," Chapter 2).

Thermoform process. A commercial name for the vacuum-forming process used by the American Thermoform Corporation (see "The Vacuum-Forming Method," Chapter 2).

Three-dimensional form. A form that can be measured in length, width, and height or diameter.

Thumb index. A series of indentations cut into the edges of the pages of a book to facilitate quick reference.

Tick marks. See **Scale marks.**

Tongs (also called *freehand drawing stylus*). An embossing instrument that enables the user to correct braille text on a display by adding a single dot to the braille cell. It can be used to emboss simple outline figures and lines in a display (see "Embossed Displays," Chapter 2).

Topology. The study of the surface features of a given region, presented on a map to show the relative positions and elevations within the area.

Tracing paper. Translucent paper or plastic used to transfer words or images from one surface to another.

Tracing wheel. See **Spur wheel.**

Transfer lettering. See **Instant dry-transfer lettering.**

T Square. A t-shaped ruler used in drawing horizontal or parallel lines.

Two-dimensional form. A flat form that is measured in two dimensions—length and width—but not breadth or depth.

Undercutting. Cutting material under or on a slant so that the surface layer overhangs the layer or area beneath it. Undercutting can cause difficulties if it occurs in a display that will be mass-produced in a vacuum-forming machine. The plastic sheet that forms the

copy will creep into the undercut area during production, making it impossible to remove it without destroying the master.

Underlay. See **Overlay.**

Uppercase. Of or relating to the large letters of a type family, as opposed to **lowercase**, the small letters of a type family.

Vacuum-forming method. The process of making plastic copies from a master through heat and the use of a vacuum (see "The Vacuum-Forming Method," Chapter 2).

Vanishing point. The point in a perspective drawing where parallel lines appear to come together on the horizon.

Varnish. A preparation consisting of a solvent, a drying oil, resin, rubber, and the like that produces a hard, glossy, transparent coating when applied to a surface.

Velcro. The commercial name of self-adhesive material that can be used in displays with movable parts.

Visual impairment. A defect or malfunctioning of the eyes resulting in diminished vision and affecting the individual's ability to perform the usual tasks of daily life. Visual impairments encompass a wide range of degrees of vision loss.

Volume. The extent of the three-dimensional space enclosed within an object or occupied by an object.

Illustrations

CHAPTER 1

2 Photo by Thomas Bergman.
5 Photo by Thomas Bergman.
9 Photo by Anders Enarsson.

CHAPTER 2

12 Drawing by Peter Jörnekunt. Photo by Thomas Bergman.
14 Drawing by Peter Jörnekunt.
19 (*left*) From Edman, P. K. (1970). *A letter means so much.* Danderyd, Sweden: Author. Photo by Thomas Bergman.
19 (*right*) Photo by Thomas Bergman.
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36 (*bottom*) Photo by Grahame James.
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41 (*top*) From Edman, P., & Bernhard, L. (1980). *Bild och form del 2 (Pictures and Shapes).* Solna, Sweden: RPH-SYN. Photo by Thomas Bergman.
42 (*top*) Photo by Thomas Bergman.
44 (*bottom*) Photo by Thomas Bergman.
53 Photo by Howe Press.
54 (*top*) Photo by Thomas Bergman.
54 (*bottom*) Photo by Royal National Institute for the Blind.
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58 Photo by Peter J. S. Kosmetschke.
59 Photo by American Printing House for the Blind.
61 Photo by American Printing House for the Blind.
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116 Photo by Thomas Bergman.
118 Photo by Thomas Bergman.
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161 From Fellenius, K., Lindblad, I., & Edman, P. (1979). *Bokstavsboken*. Solna, Sweden: RPH- SYN. Photo by Thomas Bergman
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